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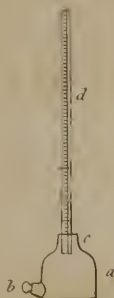


Fig. 2

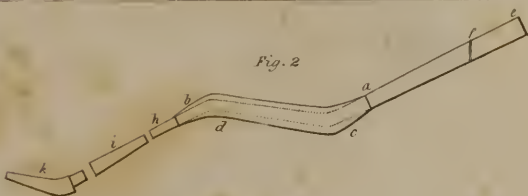
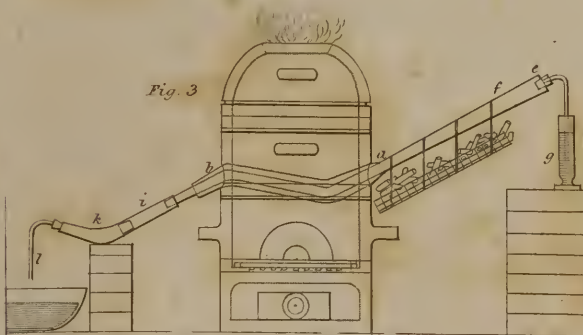


Fig. 3



JOHN GREEN.
THE
ELEMENTS
OF
CHEMICAL SCIENCE.
IN TWO VOLUMES.

WITH PLATES.

BY JOHN GORHAM, M. D.

MEMBER OF THE AMERICAN ACADEMY, AND PROFESSOR OF CHEMISTRY
IN HARVARD UNIVERSITY, CAMBRIDGE.

Homo naturæ minister et interpres.
Bacon.

VOL. II.

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ANNEX
Chemistry

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"The Elements of Chemical Science. In two volumes. With plates. By John Gorham, M. D. Member of the American Academy, and Professor of Chemistry in Harvard University, Cambridge. Homo naturæ minister et interpres.—Bacon."

In conformity to the Act of the Congress of the United States, entitled, "An Act for the encouragement of learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the times therein mentioned;" and also to an Act, entitled, "An Act supplementary to an Act, entitled, An Act for the encouragement of learning, by securing the copies of Maps, Charts, and Books to the authors and proprietors of such copies during the times therein mentioned; and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

JNO. W. DAVIS,

Clerk of the District of Massachusetts.

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ERRATA &c.

Page 3 line 7 from the top, for *tenacity* read *tenuity*.

100 5 from the bottom, *iodate* *iodide*.

260 8 from the top, *platium* *platinum*.

379 last line, in a few copies, for 5, and in others for 50, read 7.50.

407, 408, and 412, are by mistake printed 307, 308, 142.

413 line 7 for *scented*, read *secreted*.

459 for Sec. II, read Sec. III, and correct the Sections accordingly
pp. 463, 471, 476, 478, 480, 481, 484.

520 in a few copies, for *Antiomy* read *Antimony*.

ELEMENTS
OF
CHEMISTRY.

=
PART II.

=
CHAPTER V.
OF THE METALS.

DII. **T**HE properties of this class of bodies are so important, and the uses to which they have been applied so numerous, that the metals have always constituted an interesting subject of research to the chemist and the philosopher. The improvements in science and the arts, and the comforts as well as the refinements of society may be considered as dependent, in a great measure, upon their application to the various objects of human industry. The ancients were acquainted with gold, silver, copper, iron, lead, tin, and quicksilver; and such were the benefits derived from their use, and so great the difficulty of working them, that they deified those who taught them to subject the metals to the rules of art. Little however was known of their chemical relations, until the time of the alchemists. The hope of discovering a mode by which the less valuable metals might be transmuted into gold, stimulated these men to the most unwearied and extraordinary exertions; and though they failed, it is to their empirical experiments that modern chemists are indebted for the knowledge of many of the properties and important compounds of metallic bodies.

DIII. Before entering upon the description of the individuals of this class, it will be proper to take a cursory view

of the qualities which characterize the metals and distinguish them from other bodies. These may be divided into mechanical and chemical.

Mechanical properties. These are colour, lustre, opacity, density, hardness and elasticity, ductility, malleability, tenacity, structure or texture.

Colour. Diversity of colour is not characteristic of the metals. Few of them are deep, and for the most they are white, with shades of blue or red. Gold is yellow, copper reddish yellow, silver shining white, titanium red, osmium black or deep blue. Tin, platinum, palladium, nickel, mercury, iridium, and tellurium are white, and possess a brilliancy inferior only to that of silver. Antimony, zinc, lead, and iron, are bluish white; the following are grayish white, potassium, sodium, manganese, arsenic, cerium, rhodium; molybdenum and uranium are of a deep gray colour; and bismuth yellowish.

Lustre. One of the most remarkable properties of metals is their lustre. When polished, they are always shining, and their fractured surfaces present in a greater or less degree the same appearance. This property exists even when they are reduced to powder. In this therefore they differ exceedingly from bodies of an earthy nature; and the quality is so constant, that it has acquired the name of metallic brilliancy.

Opacity. The metals as commonly presented to us are completely impervious to light. Yet in certain circumstances it has long been known that some of them are diaphanous. Though tin-foil $\frac{1}{1000}$ of an inch in thickness, and silver leaf which is only $\frac{1}{180000}$ of an inch thick, are opaque, gold leaf is translucent, and when held between the eye and a luminous object, transmits so much light of a bluish green colour, as to permit the form of the object to be distinctly visible. It has been thought by some, that this quality in gold is accidental, and may be owing to the minute fissures produced by the inequalities of the gold-beater's skin. But if this were

the case it might be supposed that other metals, when beaten to their greatest extent, would exhibit the same effect. As gold is the most malleable of metals, its leaves are thinner than those of others, and may therefore acquire this property; and as it is likewise the densest, with the exception of platinum, it may be supposed that all the metals, when reduced to a certain degree of tenacity, will become translucent.

Density. The properties of lustre and opacity were, until lately, conceived to depend to a certain degree upon the greater specific gravity of the metals over that of all other bodies, or the quantity of matter contained in a given space, but this opinion can be no longer supported, because the same properties are exhibited by the metals of the alkalis which are even lighter than water. The relative weights of the individuals of this class are very different. The specific gravity of platinum is 20.5; of gold 19.25; of mercury 13.5; of iron 7.78; of tellurium 6.11; of potassium 0.865,* and of sodium 0.972. The densities of the other metals are intermediate.

Hardness and Elasticity. The same difference is observed in these properties, as in the densities of the metals. There is no metal in its pure state which is not susceptible of being scratched or furrowed by some of the gems; yet some of them, such as iron and manganese, possess a great degree of hardness. Others on the contrary, as for example, lead, are so soft as to be marked by the nail; potassium and sodium at common temperatures have the consistence of wax, and mercury is perfectly liquid. It is well known however that some individuals of this class may be rendered much harder by art, and the file and blades of cutting instruments, which are formed by certain processes from iron, exhibit this property in a remarkable degree. Elasticity and sonorousness, or the power of communicating sound, are dependent upon the hardness, and the same methods, which are practised to increase the latter, also augment the former. Iron

* Gay-Lussac and Theaard.

in its usual state presents but little elasticity, but in the form of steel it is employed in the formation of springs for different kinds of machinery. Bell-metal results from melting together in certain proportions tin and copper; the compound is harder than either of its ingredients, and is likewise more sonorous and elastic.

Ductility. Many of the metals possess the power of being drawn into fine wire. Iron may be thus extended until it does not exceed human hair in thickness. Boerhaave mentions the name of an artist whose dexterity was such as to extend a grain of gold to the length of 500 feet; but in this he has been exceeded by Dr. Wollaston. The method of this philosopher consisted in drilling a hole through silver wire, inserting into it a wire of gold, and passing it through the wire-drawing machine. In this way a fine thread of silver, including a more attenuated wire of gold, was obtained, and they were afterwards separated by immersing all the wire excepting the two ends in nitric acid, which dissolved the silver but left the gold unaltered, and the ends which were still coated with silver were employed as handles to raise the almost invisible wire of gold. By this mode a wire may be formed only $\frac{1}{30000}$ of an inch in thickness, so fine indeed that 700 feet of it shall weigh only one grain. Silver is likewise very ductile, and the property is also possessed to a considerable degree by platinum and palladium, and by some of the compounds of the metals, particularly brass.

Malleability. Nearly allied to ductility is the power of being beaten into thin leaves. The most ductile, generally speaking, are likewise the most malleable. A grain of silver may be extended under the hammer, and at the same time possess sufficient firmness to form a hemispherical cup, capable of containing an ounce of water. Silver leaf is only $\frac{1}{100000}$ of an inch thick. Gold is still more malleable, for one grain may be beaten so fine as to spread over more than 65000 times its original surface; and the thickness of its leaf is $\frac{1}{282000}$ of an inch. Platinum and palladium, brass, and

tin with a small proportion of lead, may be rendered very thin by percussion; but iron, though it be ductile, cannot be reduced to thin laminæ.

Tenacity. By this term is meant the power of supporting a certain weight without breaking. The metals differ from each other exceedingly in this property, and among them it is possessed in the greatest degree by iron. A rod of this metal, the base of which is an inch square, will support a weight, according to the experiments of Muschenbroëk, little less than 74500 pounds; gold of the same diameter will be broken by 22000, tin by 4400, and lead by 860 pounds. Iron in the form of steel will support of all the metals or their compounds the greatest weight. Cohesive attraction operates, therefore, with prodigious force, and it is probably upon this property and the form of the particles depend those of ductility, malleability, and elasticity.

Structure or Texture. The structure of many of the metals appears to be crystalline, and sometimes by certain methods even the form of the crystals may be developed. Iron is fibrous, as has been shown by Mr. Daniell.* Bismuth and antimony are lamellated, and nickel presents a fracture between fibrous and foliated, while steel is granular. But in melting a mass of bismuth in a crucible and, when a crust is formed upon the surface, piercing it and allowing the liquid to flow off, the cavity thus formed will be found covered with beautiful and perfect cubic crystals. Arsenic may be crystallized in regular tetraedra, and titanium in long and slender filaments or prisms. Native silver is likewise found in a plumose or arborescent form, and gold occasionally in cubes, octaedra, or dodecaedra. This difference in texture may perhaps account for the various degrees of ductility, tenacity, and malleability, exhibited by different metals.

DIV. Such are the mechanical properties of the metals; we may now consider them chemically in their relations to

* Journal of Science and the Arts, vol. ii. 278.

caloric and electricity, to the supporters of combustion, to the simple inflammable bases, and to each other.

Relations to caloric, and electricity. Of all bodies the metals are the best conductors of caloric, a circumstance, which in comparing them with other classes of matter, probably depends upon their density. But in this respect they differ among themselves, and the heaviest are not the best conductors, for this property exists in a less degree in platinum and palladium than in silver; and silver is inferior to copper.

In comparing the individuals of this class the same difference is found to obtain in their *expansibilities* by heat. On inspecting the tables of Mr. Smeaton, Mr. Troughton, and Messrs. Gay-Lussac and Arago, (LXXIX) it will be seen that they obey no general law in this respect, and that their relative powers of expansion can be determined only by experiment. The metals on exposure to heat expand in all their dimensions to certain points, beyond which they are converted into liquids. They are therefore fusible; but the temperature at which this change of form takes place varies with the nature of the individual. The melting points of no two metals are precisely the same. In order to fuse platinum or iridium it is necessary to apply the heat excited in the flame of the oxy-hydrogen blow-pipe; manganese and iron require for their fusion the temperature of the best constructed furnace; while tin melts at the 442° , potassium at 136° , and mercury at -39° of Fah. When thus reduced to the liquid state, the metals still preserve their opacity; they also retain for some time their lustre, and this property in some of them is even increased by liquefaction. The following table exhibits, so far as is known, the melting points of a number of the metals, the arrangement being similar to that adopted in the work of M. Thenard.

1. *Metals fusible below a red heat.*

Mercury	-	^{Fah.} —39°	-	Hutchins.
Potassium	-	100°	}	Davy.
		137°		Gay-Lussac and Thenard.
Sodium	-	180°	}	Davy.
		194°		Gay-Lussac and Thenard.
Tin	-	442°	-	Crichton.
Bismuth	-	476°	-	Irvine.
Lead	-	500°	}	Biot.
		612°		Crichton.
Zinc	-	666°	-	Brogniart.
Antimony	-	810°	-	Mortimer.
Arsenic	}			Undetermined.
Tellurium				

2. *Metals infusible below a red heat.*

Silver	-	^{Wedg.} 22°	-	-	Kennedy.
Copper	-	27°	}	-	Wedgewood.
Gold	-	32°		-	
Cobalt	-	130°			
Iron	-	130°	}	-	Wedgewood.
		158°		-	McKenzie.
Manganese	-	160°	-	-	Guyton.
Nickel	-	160°	-	-	Richter.

3. *Metals difficultly fusible in the highest heat of a forge, but fusible before the oxy-hydrogen blow-pipe.*

Molybdena.	Tungstein.
Uranium.	Chrome.

4. *Metals infusible in a forge, but fusible in an ignited stream of oxygen and hydrogen gases; and in the circuit of a powerful voltaic battery.*

Titanium.	Osmium.
Cerium.	Iridium.
Rhodium.	Platinum.
Columbium.	

Most of the metals may be volatilized, but the temperature required for the production of vapour is different according to the nature of the individual. Mercury boils at the temperature of about 672° , and the same effect is produced upon zinc, arsenic, potassium, and tellurium, by a degree of heat not much superior. Copper is often found in a very attenuated state in the flues of the furnaces in which its ores are reduced, and Lavoisier succeeded in gilding a silver plate by suspending it over a mass of gold, supported upon ignited charcoal, the temperature of which was rendered intensely high by a stream of oxygen gas. None of the metals can withstand the heat of the oxy-hydrogen blow-pipe, or of a very extensive voltaic battery.

Some of the metals when liquid occupy a smaller space than when solid ; this is particularly the case with iron, and it is from this circumstance that accurate and even delicate figures may be formed of this metal by pouring it in its liquid state into moulds. The volume of others on the contrary is enlarged, and they consequently contract on cooling ; such is the case with mercury, for on congealing it contracts according to Mr. Cavendish $\frac{1}{23}$ of its bulk. It was this great condensation which caused the Russian Academicians, who first perceived the congelation of mercury by a natural cold, to place its freezing point many degrees below that at which it was subsequently fixed.

Metals are the best conductors of voltaic and atmospheric electricity. The use of lightning rods and metallic conductors is familiar. But when powerfully excited either by an electrical or a voltaic battery, they become heated to ignition, melted and dissipated in globules, volatilized, or consumed, being often found after the experiment in the form of oxides. The light produced is vivid, and the colour varies with the nature of the metal. Iron burns with a lively white light ; the flame of zinc is a brilliant white, with shades of blue and red ; that of tin is bluish white ; of copper greenish white ; of silver green ; and of gold yellowish white. In

such cases the metals are employed in the form of fine wires, or of thin and delicate laminæ. The temperature excited in the circuit of the voltaic batteries of Mr. Children, and of the Royal Institution of London, appears to have been equal, or nearly so, to that of the oxy-hydrogen blow-pipe. When the former was put in action by means of a mixture of nitric and sulphuric acids diluted with water, $5\frac{1}{2}$ feet of platina wire, 0.11 of an inch in diameter, were heated to a full red, and the same effect was produced upon a wire of the same metal, 0.44 of an inch in diameter, and $8\frac{1}{2}$ feet in length. A bar of platina $\frac{1}{8}$ of an inch square and 2.25 inches long was heated red hot and fused at the end. Oxide of tungsten was fused and partly reduced, the metal being very brittle, heavy, brilliant, and of a grayish white. Of the oxide of tantalum a small portion was melted into grains, which were extremely brittle, and of a reddish yellow colour. Oxide of uranium was melted but not reduced; nor was the experiment more successful with that of titanium; but when intensely ignited the latter burned, and threw off brilliant sparks like those of iron in oxygen gas. The oxide of cerium melted, and when highly ignited, burned with a vivid white light, and was partly volatilized. The fused oxide, when exposed for a few hours to the air, was reduced to powder. The oxide of molybdena was easily fused and reduced, and the metal, which was brittle, exhibited a steel-gray colour, and was soon covered with a thin coat of purple oxide. The compound ore of iridium and osmium melted into a globule; and iridium alone was fused into an imperfect globule which was white, very brilliant, and of a specific gravity equal to 18.68. Iron containing diamond was converted into steel, and the gem disappeared.*

Mr. Children also operated upon wires which were formed of alloys or compounds of different metals, and in all cases the phenomenon of ignition was observed, and in some that of fusion. It was inferred by this gentleman, that the

* Philosophical Transactions for 1815.

power of becoming ignited was in the inverse ratio to the property of conducting electricity ; in other words, that those metals which conduct the best are the least easily ignited in the electrical circuit. It appears from the experiments of Van Marum, that a charge of the same force from an electrical battery sent through wires of different metals of equal diameter, melted portions of each differing exceedingly in length ; for the power which fused only 0.25 of an inch of copper or silver wire, melted $3\frac{1}{2}$ of gold, 5 of iron, 120 of tin, and 120 of lead wire. Whence the conclusion has been drawn, that the conducting power of copper or silver is much greater than that of lead or tin. Experiments of the same nature were made with the voltaic apparatus of Mr. Children, and from their results the relative conducting powers of six metals were as follows, silver, zinc, gold, copper, iron, platina. It is stated as a fact, that when metals are ignited by electricity they remain longer red-hot, than when the same effect is produced by a common fire.

The metals are also remarkable for their *electro-motive* power, and they constitute the substances of which are formed combined voltaic arrangements. The effects are more positive in proportion to the difference in their attractive powers for oxygen ; hence the pile, or battery, which is formed of zinc and silver plates, is more energetic than that in which zinc is associated with copper.

Relations to the supporters of combustion. All the metals are inflammable, and when sufficiently heated in contact with the air, they take fire, consume brilliantly, and produce flames which are differently coloured. The temperature required for this effect varies with the metal. When zinc is heated to ignition in a common crucible, it becomes inflamed and burns with a beautiful greenish white light. Tin during its combustion produces a flame tinged with light shades of green and blue ; copper affords a green light, while the flame of silver is greenish white, and that of gold yellowish white. Iron heated to whiteness and immersed in oxygen gas burns

vividly, and throws off occasionally sparks of intense brilliancy. Platina requires for its combustion the prodigious heat of the oxy-hydrogen blow-pipe. In all cases in which these bodies are consumed in the open air, or in oxygen gas, they are found to increase in weight, their properties experience an obvious change, and the products consist of the metals in combination with oxygen. Hence they are known in modern chemistry by the name of *oxides*, and this act of mutual combination is characterized by the term *oxidation*, or *oxidizement*.

Metals may be oxidized either directly by bringing them into contact with oxygen, or indirectly by decomposing atmospheric air, water, or the acids. According to M. Thenard the action of oxygen upon the metals depends on its hygrometric state; that is, whether it be dry or moist. At the ordinary temperature of the air dry oxygen is absorbed by potassium, but neither by sodium, nor by any of the common metals. But when the gas is humid, it not only oxidizes the alkaline metals, but many of those also which have a less powerful affinity to this element. In the first case the water is presumed to be decomposed, its oxygen is transferred to the metal, while its hydrogen is disengaged. Thus potassium on exposure to the air for a few seconds becomes tarnished, a white crust forms upon its surface which attracts moisture from the air, this in its turn is decomposed, and the absorption of free oxygen, and the decomposition of the water go on until the whole of the metal is converted into potash. In the second case, the vapour of the water, in becoming liquid by changes of temperature, dissolves a portion of oxygen, and by thus depriving it of elasticity, renders it susceptible of union with the metal; and the combination is still further favoured by the tendency of the oxide thus formed to enter into union with the water, and to produce a compound, which is known by the name of hydrate. The metals, which are oxidized with the greatest facility in this way, are arsenic, iron, manganese, zinc, lead, copper.*

* Thenard. *Traité de Chimie*, t. i. p. 253.

The combination of a metal with oxygen in its usual hygrometric state is facilitated by heat. Many of those metals which are slowly oxidized on exposure to the air at common temperatures, may be rapidly converted into oxides, without the usual phenomena of combustion, by preserving them at their melting points. The lustre of liquid lead soon ceases, at least at the surface, and a crust forms which consists of the metal in union with oxygen. The same phenomenon is presented by melted zinc, bismuth, tin, &c. The effect of heat in favouring this oxidizement is presumed to depend upon the diminution of cohesion in the metal, by which the force of the affinity between the two is apparently increased, or rendered more effectual. It has the same influence, though in a less degree, when the temperature of the metal is below that which is necessary for its fusion. Some of the metals, such as gold and silver, require an exposure for a long time to the air and to an intense temperature to be in part converted into oxides; and the oxides of these metals obtained from acid solutions may be decomposed by the sole agency of heat.

Metals also may be oxidized by decomposing water. The *rusting* of iron probably results from the joint influence of the oxygen, the carbonic acid, and the hygrometric water of the atmosphere. The process goes on slowly, but the metal may be made to produce the decomposition of water rapidly by the agency of an acid. Thus when immersed in diluted sulphuric acid, an effervescence immediately takes place, and hydrogen gas is disengaged. The acid which remains will saturate the same quantity of alkali, as an equal weight of the acid in a free state; hence we may conclude that it is not decomposed in this experiment, but that the oxygen which is found combined with the iron is derived from the water. The operation of the metals, which have strong affinities for oxygen, upon the acids, depends upon the strength of the attractions which subsist between the elements of the latter. Iron, as we have said, does not decompose sulphuric acid at

common temperatures, but if it be immersed in nitric acid the process of oxidizement immediately commences, and great quantities of nitric oxide gas are produced. If, however, the acid be diluted, so that the action shall be moderate, it will be found that the water, as well as the acid itself, has been decomposed; for when the solution is saturated with lime, the odour of ammonia becomes perceptible, and this compound is formed by the union of the hydrogen of the water with part of the azote of the acid; when thus formed it unites with a portion of the acid, and constitutes nitrate of ammonia, which is decomposable by quick-lime. It appears that where the proportions of oxygen in an acid are not numerous, or where its elements are retained by a strong affinity, it effects the oxidizement of the metals by enabling them to decompose water, in consequence of the exertion of what has been called *disposing affinity*. But when oxygen is combined in several proportions with a base, which itself does not exhibit powerful affinities, the metals then become oxidized by attracting the higher proportions of oxygen from the radical of the acid, and in such cases the decomposition is rapid. Upon this principle may be explained the energetic action of the metals upon nitric acid. They even decompose this compound when previously combined with the salifiable bases; if a mixture of powdered antimony and nitrate of potash be projected into a red hot crucible, deflagration takes place, and the results are oxide of antimony and potash.

But the acids, which at common temperatures oxidize metals by causing them to decompose the water present, may be themselves decomposed by raising them to a boiling heat; hence quicksilver and copper, which do not act in the cold upon sulphuric acid, separate its elements with facility when heated in contact to about 600° ; in this case, however, one proportion only of the oxygen is transferred to the metal, while the remaining oxygen, still in union with the base, passes off in the form of sulphurous acid.

When a metal has become oxidized in liquid acids, either by decomposing the water, or a portion of the acid itself, the oxide combines with that part which is still undecomposed, and forms with it a metallic salt. If a salt of this description be decomposed by the addition of another salifiable base, the metal is precipitated, not in its pure and simple state, but in combination with oxygen, or in the form of an oxide. Hence it may be inferred, that solutions of metals in acids are solutions of metallic oxides. This conclusion, however, does not necessarily follow, for some of the salts commonly called muriates are considered as binary compounds of metallic bases with chlorine, for example, muriate of lime, which is a chloride of calcium, and when potash is added to it, its oxygen may be transferred to the calcium, forming lime which will be precipitated, while the potassium takes its place with the chlorine. There are likewise some exceptions to the general rule, that the oxides formed in contact with acids subsequently unite with them to produce neutro-saline compounds; for bismuth, tin, iron, zinc, &c. when made to act upon undiluted nitric acid, become so highly oxidized as to be rendered incapable of combining with, or of remaining in solution in the portion which is still undecomposed.

The metals, generally speaking, combine with more than one proportion of oxygen, and the fact appears to be established, that the higher proportions are multiples of the first. Thus mercury, gold, iron, tin, &c. unite with two proportions, and antimony, according to Berzelius, with three of oxygen. These oxides generally presenting different colours were formerly designated by this difference; thus we have the black and red oxides of iron, the purple and yellow oxides of gold, &c.; but there was evidently a want of precision in this mode of designating them, for in some cases it happens that both oxides of a metal are either of the same colour, or are white, and in order to distinguish them it is necessary to apply to one the terms oxidized at a minimum and to the other oxidized at a maximum; but this method

cannot be applicable in cases in which there exist more than two oxides of the same metal. The terms employed by Dr. Thomson were happily chosen to obviate these inconveniences, for they are both precise and expressive. He proposed to prefix to the usual name of these compounds, the first syllable of the Greek ordinal numerals, so that a metal combined with one proportion of oxygen should be recognized by the name of *protoxide*; with two proportions it should be called by that of *deutoxide*; with three proportions, *tritoxide*; and when united with the largest proportion of oxygen, *peroxide*. Thus there are a protoxide and peroxide of gold, a protoxide, deutoxide, and peroxide of antimony, &c.

The oxides, when formed by the common processes of the chemist, are destitute of metallic lustre, and analogous to earthy substances, but many of them may be obtained in a crystalline state, and even in regular geometrical figures. The peroxide of iron is found in nature beautifully crystallized in rhomboids, double six-sided pyramids, polyhedra, or thin six-sided tables, with iridescent surfaces, as seen in the ore from the island of Elba. The oxide of copper in the form of *ruby copper* is crystallized in cubes or octaedra; and the peroxide of manganese in four-sided prisms exhibiting a metallic lustre.

The oxides generally speaking are less fusible than their bases, and many of them when exposed to intense temperatures melt into glasses which are usually coloured. Hence these compounds always enter into the composition of vitreous substances which are intended as imitations of the gems. Glass is stained yellow by the oxide of antimony, red by oxide of silver, deep blue by the oxide of cobalt, green by the oxides of iron and of copper, and amethystine by the oxide of manganese. The oxides of lead constitute a part of pure and colourless flint-glass.

The force with which oxygen is retained by the metals is various. The peroxides are converted without much difficulty by the action of heat alone into protoxides or deutoxides,

by the expulsion of one or two proportions of oxygen ; but when the compound is reduced to 1 proportion of each, the decomposition ceases, and to obtain the base in its metallic state, the addition of some other substance, which possesses a powerful affinity for oxygen, is required. Thus oxygen may be obtained by a red heat from the peroxides of manganese and lead, but to reduce the protoxides of these metals they must not only be exposed to a high temperature, but to the action of carbonaceous matter. The oxides of gold, silver, platina, mercury, and a few other metals are decomposed by heat alone. The affinity of their elements is therefore comparatively feeble, and from the facility with which their oxygen may be transferred, they produce positive effects when heated, or exposed to percussion with highly combustible substances. But cerium, tungsten, uranium, manganese, and the metals of the alkalies, and alkaline earths, exert so powerful an attraction for oxygen, as to be obtained in the metallic state with great difficulty. Hence as the metals possess different attractive powers for oxygen, one of this class may be employed to reduce the oxide of another, by being heated in contact.

The peroxides of some of the metals, such as those of molybdena, chrome, arsenic, tungsten, and columbium, exhibit distinctly acid properties.

Two only of the metallic oxides are volatile, viz. those of arsenic and of osmium.

Light decomposes the oxides of silver and of gold, and it appears to operate upon the oxides of other metals by expelling a proportion of oxygen, as in the case of oxide of bismuth, which becomes yellow on long exposure even to indirect light. This principle also acts upon them even when combined with acids, and many of the metallic salts are altered by exposure to the solar rays. They are also easily decomposed by voltaic electricity, for when moistened and made to form a part of the circuit, the metal freed from oxygen will be found to collect around the wire connected with

the negative pole. The same effect is produced in metallic solutions, and the cause is probably the attractions which subsist in the different poles for the elements of the oxides, their oxygen being transferred to the positive, and their bases to the negative ends of the battery. The reduction of the solid oxides may be facilitated by electrifying them in contact with mercury, at least, in all those cases in which the basis of the oxide is capable of amalgamating with that metal. The mercury should be connected with the negative pole.

DV. One of the most interesting points in which the oxides are viewed is in relation to their combinations with acids, to their proportions, and the modes in which they decompose each other.

The oxides unite with the acids in different proportions, and if the former be considered as unity, the latter will be found combined in multiples in most of those cases in which there is more than one saline compound of the same proximate elements. Potash unites with two proportions of carbonic acid, and the bi-carbonate contains twice as much of the acid as the carbonate. The case is the same with the sulphates of potash, and sulphates of copper. In other instances the different oxides of the same metal unite with the same acid and produce salts which vary essentially in properties. Thus the black and red oxides of iron combine with sulphuric acid and form green and red sulphates. The protoxide and peroxide of copper form corresponding compounds with muriatic acid. Hence Dr. Thomson's nomenclature has been generally adopted to distinguish them, the term *proto* being added to the name of the salt containing a protoxide, and that of *per* when it contains the peroxide. Thus there are a sulphate and persulphate of mercury; a protomuriate and a permuriate of iron, &c.

The larger the quantity of oxygen combined with a metal, the greater is the amount of acid required for its neutralization. Hence it will be found, that if a solution of proto-sul-

phate of iron be exposed for some time to the air, it will gradually deposit a quantity of peroxide, and the water will hold dissolved persulphate of iron; now as the proportion of acid remains the same, it is obvious that though it was capable of saturating the protoxide in the salt dissolved, yet it was not in sufficient quantity to combine with the whole of the peroxide formed from it, although the amount of metal in each is the same. Richter, after a long investigation into the constitution of metallic salts and their mutual decompositions, inferred, 1. That all neutral salts, which remain neutral when their solutions are mixed, are so composed, that the quantities of the different bases that saturate one of the acids present in the mixture, follow the same proportions in saturating the other acids. 2. That a metallic neutral salt, the metal of which is precipitated by another metal, changes its metal only; while the portion of oxygen that enters into the metallic oxide, and the acid with which it is saturated continue the same; and that the different metallic oxides, which saturate a given portion of acid, all contain the same quantity of oxygen.*

These laws may perhaps require some illustration. Silver dissolves in nitric acid, after being reduced to the state of oxide, and forms a salt soluble in water. If a plate of copper be immersed in this solution, the silver will be precipitated in its metallic state, and the liquid will constitute a solution of neutral nitrate of copper. Now as solutions of metals in acids are in fact solutions of metallic oxides, the oxygen which is transferred from the silver to the copper, forms an oxide of copper, which is just sufficient to neutralize the nitric acid present. From this iron precipitates metallic copper, takes its oxygen and acid and supplies its place, and the phenomenon is to be explained on the same principle.

There are two important practical facts which follow from these discoveries.

* Berzelius. Nicholson's Journal, vol. xxx. p. 260.

1. They enable the chemist to find the proportions of the metals which combine with a given proportion of oxygen, and to ascertain their *equivalent numbers*, a fact which is the foundation of Dr. Wollaston's Scale. For supposing the proportion of oxygen to be the same, and (hydrogen being unity) to be designated by 7.5, then the proportional weight of some of the metals capable of uniting with 7.5 of oxygen will be as follows: tin, 56; antimony, 40.3; copper, 60; silver, 103 nearly; mercury, 187.5. &c.

2. The composition of a metallic oxide may be ascertained by the quantity of acid required for its neutralization. Thus 100 parts of sulphuric acid are saturated by a quantity of base which contains 20 of oxygen; now this quantity of acid unites with 194 of barytes; hence 194 of barytes contain 20 of oxygen; and the oxide of barium consists of 90.67 of barium, and 9.33 of oxygen. Carbonic acid unites with a metallic base which contains 36.267 of oxygen; 100 of the acid are saturated by 234.44 of strontian; and $234.44 : 36.267 :: 86.61 : 13.39$. Hence, supposing each of these bases to be combined with 1 proportion of oxygen, the equivalent number of barium will be 72.8, and that of strontium 48.4.

Besides these laws relating to the metallic combinations, Berzelius has proposed three others, which appear to be well founded.

1. The proportion of the metal and of sulphur in a metallic sulphate, is the same as in the sulphuret of the metal. Thus sulphate of copper affords just as much sulphur and copper as its sulphuret. This law is founded on the general fact, that in oxygenating the metallic sulphurets, the results are neutral sulphates. Thus nitric acid converts sulphuret of lead and sulphuret of antimony into neutral sulphate of lead, and sulphate of antimony.

2. The oxygen in a metallic protoxide is equal to half the sulphur in the sulphuret of the same metal, supposing the sulphuret to consist of 1 proportion each of its elements.

The weight of a proportion of sulphur is double that of oxygen, or as 15 : 7.5 ; whence this law is derived. It will be found that in most instances this law obtains ; but that there are some cases in which this relation between the sulphur of the sulphuret and the oxygen of the protoxide has not been observed. This discordance however arises from the difficulty of determining the number of oxides of the metals. Such is the case with platinum. This canon of Berzelius is equally applicable to deutoxides and bi-sulphurets.

3. When 2 combustible bases unite, they always combine in such proportions, as that when oxidized, either the quantity of oxygen uniting with each will be the same, or the oxygen in the one will be twice, thrice, &c. that in the other.*

DVI. The metals combine with chlorine and form peculiar compounds, which are known by the name of *chlorides*. The combination in some instances is rapid, and accompanied with the evolution of light and heat, while in others it takes place more gradually without producing the phænomena of combustion. Antimony, arsenic, bismuth, tin, iron, copper, and potassium, when projected in filings or thin laminæ into dry chlorine, take fire, and produce abundance of dense fumes. Most of the metals combine with two distinct proportions of chlorine, forming compounds which are designated by the names of *protochlorides* and *perchlorides* ; such is the case with tin, copper, iron, mercury, &c. When some of these chlorides are brought into contact with water, the liquid is decomposed, oxygen is transferred to the metal, and hydrogen to the chlorine, by which muriatic acid and an oxide are formed ; and these by their subsequent union constitute a muriate. Of these an example is furnished by Libavius's liquor, or what has been called the oxy-muriate of tin.

DVII. The metals and iodine readily enter into union, but the combination produces little heat, and is rarely attended with the phænomenon of light. The compounds thus formed

* Annals of Philosophy, vol. ii. p. 32.

are called *Iodides*, and vary in colour according to the nature of the metal. The iodide of zinc is white, that of potassium has a pearly lustre and a crystalline texture, and the colour of iodide of tin is orange yellow. Of the two iodides of mercury one is red and the other yellow, and both are fusible and volatile. All these iodides are decomposed by concentrated nitric and sulphuric acids, the metals being changed into oxides, and the iodine disengaged. They are likewise decomposed at a red heat by oxygen, excepting those of potassium, sodium, lead, and bismuth. Iodine is separated by chlorine from all the metals.

When iodine and the metallic oxides are made to act upon each other in contact with water, that liquid is decomposed, its hydrogen unites with one portion of the iodine, and its oxygen with another portion, so that the results are hydriodic and iodic acids. But these are obtained only in the case of the oxides of the alkaline metals. The conclusions drawn by M. Gay-Lussac from his investigation into this subject are,

1. That the metallic oxides in which the oxygen is very much condensed, and which completely neutralize the acids, occasion with iodine the decomposition of water, and produce iodates, and hydriodates.

2. That the metallic oxides in which the oxygen is still very much condensed, though less than in the preceding, and which do not completely neutralize the acids, do not produce with iodine a force sufficiently great to decompose water and form iodates.

3. That the oxides in which the oxygen is weakly condensed, cannot concur with iodine in decomposing water; but that they convert iodine into an acid by yielding to it a portion of oxygen.*

DVIII. *Relations to unmetallic combustible bases.* There is no individual belonging to this class which is not capable of com-

* Gay-Lussac, Memoir on Iodine—Translated. Annals of Philosophy, vol. v. p. 113.

binning with one or more of the metals. There is good reason to believe that by voltaic arrangements, hydrogen may be made to form a solid *hydruret* with tellurium. In the state of gas it dissolves potassium and arsenic. Azote, according to M. Thenard, combines with potassium and sodium.* Silicon enters into combination with iron, and boron with iron and platinum. Steel is a compound of iron and carbon; and sulphur and phosphorus appear to have an affinity for all the metals. The compounds of the two last are designated by the terms *sulphurets* and *phosphurets*. Many of the metals combine with more than one proportion of sulphur, and the compounds thus formed differ in properties, as well as in their action upon the acids, which are operated upon more readily by the *sulphurets* than the *bi-sulphurets*.

The metallic oxides are also susceptible of decomposition by this class of bodies, and particularly when heated in contact with carbonaceous matter. The temperature required varies with the oxide; in many cases it is effected with great difficulty, while in others it is performed with facility. The alkaline oxides resist the action of carbon, but it has been shown by M. Curaudau, that potash may be decomposed by the joint affinities of carbon and hydrogen. In these processes when the metals are deprived of their oxygen they are said to be *reduced*; excepting mercury, for when this metal is obtained in its metallic state from its combinations, it is said to be *revived*. Hydrogen in its gaseous state possesses the power, from its strong attraction for oxygen, of reducing many of metallic oxides, a fact which was discovered by Dr. Priestley. It was afterwards ascertained by Mrs. Fulhame, that the same effect might be produced when the oxides were in combination with acids, in the form of saline solutions; by immersing a piece of muslin, for example, in these solutions, moistening it with water, and exposing it to the action of the gas for some time, the metal was reduced, and this method was successfully employed to gild various delicate

* *Traité de Chimie*, t. i. p. 256, 2d edition.

articles. The same result was obtained by the use of charcoal and phosphorus, but in all cases it was necessary that water should be present, and in many, that the substances should be exposed to the direct action of solar light.* The power of phosphorus to precipitate the metals from their saline solutions was observed in 1781, and as Pelletier had shown that this substance was capable of combining with some of the metals, it was inferred by M. Borthollet, that the precipitation was owing partly to the affinity of the phosphorus for their oxygen, and in part to its disposition to combine with such metals; wherever therefore these two forces co-operate, the decomposition may be produced, as in the cases of gold, silver, copper, and mercury.† This explanation may account for the action of phosphorus on metallic solutions, but the precipitation of the metals by charcoal must be owing to its affinity for oxygen alone, for it does not combine, so far as we know with any of the metals above mentioned. In fact, as exposure to the solar rays seems necessary for the reduction, it is probable that light is the chief agent in these decompositions, for a solution of muriate of gold alone will exhibit gold in its metallic state after having been acted upon for some time by the beams of the sun, as was observed by Scheele.‡

DIX. Relations to each other. The metals are susceptible of union with each other and of forming important compounds, which are known by the name of *alloys*. The metallic combination of mercury however is designated by the term *amalgam*. Alloys are formed by melting the metals in contact; but when one which is volatile is to be combined with another more fixed, the former is presented to the latter in the state of vapour. Thus zinc is made to unite with copper in the formation of brass; and an alloy of arsenic and copper is produced in the same way. All the alloys with the exception of that of

* Essay on Combustion.

† Researches into the laws of Affinity, p. 125.

‡ Experiments on Air and Fire, p. 82.

potassium and sodium, are solid at common temperatures, and their colours vary with the nature and proportion of the metals; they possess metallic lustre, are many of them susceptible of crystallization, are harder, more brittle, and of a specific gravity either greater or less than the mean of their constituent parts. These compounds are generally more fusible than the least fusible metal entering into their composition. This is remarkably the case with the fusible metal, as it is called; it is composed of 8 parts of bismuth, 5 of lead, and 3 of tin; neither of these metals melts below 442° , yet when exposed to heat after fusion and combination, the alloy will become liquid at 212° . An analogous fact may be found in the compounds of the earths, as they were formerly called. Compounds of metals tarnish on exposure to the air much more quickly than the metals of which they are formed; and if two oxidable metals be brought into contact under the surface of water, they will combine with oxygen, or be oxidized more rapidly, than if immersed singly in the liquid. The alloys are extensively employed in the arts. Brass is an alloy of copper and zinc; bell-metal and bronze of copper and tin; printer's types of lead, antimony, and tin; pewter of lead and tin; gold and silver for commercial purposes are combined with copper.

Compounds of metals with mercury are either fluid or of a soft consistence; they are generally white, are susceptible of crystallization, tarnish rapidly in the air, and are decomposable by heat, the mercury being driven off in vapour. The amalgama most readily formed are those of the alkaline metals, and gold, silver, zinc, tin, lead, and bismuth.

DX. In treating of the individual metals, I shall arrange them according to their relations to oxygen, and adopt the plan of M. Thenard. The subjects of this chapter may be formed into six divisions.

DIVISION I.

Bodies which from analogy are considered metallic, but the oxides of which have not been completely and unequivocally reduced.

Aluminium	Ittrium
Zirconium	Glucinium
Thorinum.	

DIVISION II.

Metals which absorb oxygen, and rapidly decompose water at all temperatures.

Potassium	Barium
Sodium	Strontium
Lithium	Calcium
Magnesium.	

DIVISION III.

Metals which absorb oxygen at high temperatures, and which when heated to redness decompose water.

Iron	Zinc
Tin	Manganese
Cadmium?	

DIVISION IV.

Metals which absorb oxygen at temperatures below redness, but which are incapable of decomposing water either above or below ignition.

Arsenic	} acidifiable
Molybdenum	
Chrome	
Tungsten	
Columbium	
Selenium	
Antimony	
Tellurium	
Cerium	
Cobalt	
Titanium	
Bismuth	
Copper.	

DIVISION V.

Metals which, when heated to a certain temperature, absorb and retain oxygen, but which again evolve it at higher temperatures.

Mercury

Lead

Nickel.

DIVISION VI.

Metals which neither absorb oxygen nor decompose water at any temperature ; but the oxides of which are reducible at a heat below redness.

Gold

Palladium

Silver

Iridium

Platinum

Rhodium

Osmium.

The two first divisions include those substances which were designated by the names of earths and alkalies.

DIVISION I.

Of bodies which from analogy are considered as metallic, but the oxides of which have not yet been completely reduced.

SECTION I.

Of Alumium.

DXI. When pure liquid ammonia is poured into a solution of alum in about 15 or 20 parts of water, a precipitate is formed, which constitutes the substance called alumina. To be obtained perfectly pure, it requires to be redissolved in nitric acid, and its sulphuric acid separated by solution of nitrate of barytes. The liquid is then to be filtered, again decomposed by ammonia, the precipitate is to be well washed with distilled water, and subsequently dried at a red heat.

The nature of this white powder is not exactly known, but there is sufficient evidence that it consists of more than one

element. Sir H. Davy in the year 1808, by fusing iron negatively electrified in contact with it, obtained a globule of metal whiter than pure iron, and which when thrown into water, slowly effervesced, became covered with a white powder, and dissolved in muriatic acid and decomposed by ammonia, afforded alumina and oxide of iron. More positive effects were produced by transmitting the vapour of the metal called potassium over the surface of alumina heated to whiteness, the greatest part of the potassium was converted into potash, and disseminated through the mass were numerous gray particles exhibiting a metallic lustre, which on exposure to the air were converted into a white powder, and thrown into water slowly effervesced.*

From these facts it may be concluded that alumina consists of oxygen combined with a base which apparently possesses metallic properties. It is not yet known in what proportions these elements exist in it. Sir H. Davy and Professor Berzelius have both endeavoured to establish this point by ascertaining the quantity of ammonia required to decompose saturated solutions of alumina in acids.†

By the former it is considered as a compound of 1 proportion of each, and the number for alumina is 48, and that for its base 33. Berzelius states the proportion at 47 of oxygen and 53 of alumium. If the calculation of the latter chemist be adopted, and if the compound consist of 1 proportion each of oxygen and radical, the number representing alumium will be about 85, and that for alumina, 16.

DXII. The oxide of alumium, or alumina obtained by the method above mentioned, is in the form of a fine white powder destitute of taste and smell, smooth to the feel, and adhering to the tongue. When breathed upon it emits a peculiar odour which characterizes its native combinations, and which has been called the *earthy*. Its specific gravity is about 2.00.

* Phil. Trans. for 1808. Elements of Chem. Phil. Part i. p. 355.

† Ibid. p. 357.

Alumina absorbs water with avidity, and with a certain proportion forms a ductile tenacious mass. It is the presence of this compound which gives this property to the natural clays. The attraction between alumina and water appears to be very strong, for according to Theo. De Saussure it retains 15 per cent. of water even after having been heated to ignition. It must be considered as a chemical compound, and it has accordingly received the name of hydrate. This hydrate of alumina exists native in the mineral which is known by the name of Wavellite, and which contains, according to the analyses of Sir H. Davy and Mr. Gregor, 48 per cent. of water.

Alumina requires a very intense temperature for its fusion, but it was melted into a white semi-transparent globule both by Lavoisier and Guyton, by exposing it to a stream of oxygen gas directed upon burning charcoal; and the same effect was readily produced before the flame of Dr. Hare's oxygen-hydrogen blow-pipe.

With the oxide of silicon or silex it combines both in the humid and the dry way. Guyton ascertained that when solutions of *silicated potash*, and of a compound of alumina and potash were mingled, the silex of the one and the alumina of the other were precipitated in combination, forming a peculiar compound. A more important compound of these oxides is obtained by melting them together at an intense temperature. The result is a glass or enamel, translucent, of a pearly lustre, and of great hardness. It is porcelain.

Chloride or Oxy-muriate of Alumina.

DXIII. This compound may be formed, according to the directions of Mr. Wilson, by adding to a clear solution of oxy-muriate of lime in water, of the specific gravity of 1.060, a solution of alum of the specific gravity of 1.100, so long as any precipitate continues to fall. It is inferred by him that a double decomposition takes place, sulphate of lime being precipitated, and oxy-muriate of alumina remaining in solu-

tion. The liquid gives out a slight odour of chlorine. When it has become clear, it is to be poured off and preserved in well closed vessels. The important fact is stated by Mr. Wilson, that it may be used as a bleaching liquid in some cases in which oxy-muriate of lime cannot be advantageously employed, for example, in the whitening of fine linens, where it is an object that no lime should be fixed in the fabric of the cloth, which is always the case when the compound of lime is employed. Its rapidity of action is also greater than that of a watery solution of chlorine. Mr. Wilson has successfully applied this liquid to the purpose of discharging the Turkey red dye, which resists the power of compounds of chlorine with other bases; and he states that it may be employed with the same success in removing a variety of other colours.*

Salts of Alumina.

DXIV. Fluatc of Alumina. This salt, obtained by M. Gay-Lussac by pouring a solution of neutral fluatc of potash into a solution of alum, is white, insipid, insoluble in water, and decomposed with difficulty by acids.

Muriatc of Alumina. It is formed by dissolving alumina in muriatic acid. When evaporated far, it acquires the consistence of jelly which is uncrystallizable and deliquescent. Its taste is astringent and acid, and it is decomposed by heat. It consists, according to Mr. Dalton, of 59.5 of acid and 40.5 of alumina.

Nitratc of Alumina. Gelatinous, but forms soft crystalline scales. Its taste is astringent and acid; it is soluble in water, deliquescent, and decomposable by heat.

Sulphatc of Alumina. When alumina is dissolved in sulphuric acid, the solution is evaporated to dryness, redissolved in water, and then evaporated to a certain degree, a magma is formed, from which are deposited thin, soft plates of a

* *Annals of Philosophy*, vol. viii. p. 125.

pearly lustre, of an astringent taste, and soluble in water. Exposed to heat this salt loses its water of crystallization, and then if the heat be high it is decomposed, its acid being evolved.

Alum. If to a solution of the above salt, a few drops of a solution of potash be added, the liquid after due evaporation will yield perfect crystals of *alum*. This important salt then is not simply a sulphate of alumina, but a triple compound of sulphuric acid, alumina, and potash. It has been found however that ammonia will answer the same purpose as potash; hence it has happened that several varieties of alum are met with in commerce. These varieties, according to M. Vauquelin, are

1. Sulphate of alumina-and potash.
2. Super-sulphate of alumina-and-potash.
3. Super-sulphate of alumina-and-ammonia.
4. Super-sulphate of alumina-potash-and ammonia.

The neutral compound sulphate, formed by boiling pure alumina with a solution of alum, is solid, pulverulent, insipid, not crystallizable, and is easily converted into alum by the addition of sulphuric acid.

The super sulphate of alumina and potash is easily formed; it has the properties of alum, but is not often found in commerce. The same observations are applicable to the super sulphate of alumina and ammonia.

The true alum of commerce consists, according to M. Vauquelin, of sulphuric acid, alumina, potash, and ammonia.* It is obtained for the arts from the alum slate or earth, which contains either sulphur or sulphuret of iron, and the process consists in communicating oxygen to the sulphur by slow and imperfect calcination, by which it is converted into sulphuric acid. This acid then unites with the alumina, which constitutes the basis of the slate, and with the potash which is

* Nicholson's Journal, vol. i. 4to. p. 318.

one of its ingredients, and forms a salt that is dissolved by the affusion of water. At a certain stage of the process, a quantity of potash, and of urine which contains ammonia, is added, the whole is concentrated by evaporation, and the mass of small and imperfect crystals is made to assume the form of large and perfect octoedral crystals by the process of purification, which is called *rocking*. The use of the potash or ammonia, or both, is not merely to dispose the compound of acid and alumina to crystallize, but to combine with them, and constitute a triple or quadruple salt, which is less soluble than the acid sulphate of alumina.

The alum of commerce is in the form of large amorphous masses of a crystalline texture, colourless and transparent. It may however be crystallized in large and regular octoedra; and the same forms may be developed in a piece of common alum by the process of solution in water, as discovered by Mr. Daniell. Its taste is sweetish and strongly astringent. It is soluble in about 15 parts of cold water, and less than its own weight of boiling water. Alum contains an excess of sulphuric acid; it gives a red tinge to vegetable blues; and effervesces with alkaline carbonates. It is slightly efflorescent. Exposed to heat it undergoes aqueous fusion, and when its water of crystallization is driven off, there remains a dry white mass, which is familiarly known by the name of *burnt* or *calcined* alum. By this process it loses about 44 per cent. in weight. By increasing the heat the salt is decomposed, and its acid furnishes oxygen and sulphurous acid.

DXV. Alum is decomposed by several substances, particularly on being heated in contact with carbonaceous matter, and this decomposition produces a preparation which exhibits singular properties, and which for some time attracted a great deal of the attention of Chemists. It is called *Pyrophorus*. The mode of preparing it was discovered by Homberg, and improved by Lemery. It consists in mixing two parts of powdered alum with one part by weight of flour, or brown sugar, or as some affirm, equal parts, and exposing the mixture in an iron

ladle to heat ; it soon becomes liquid, and is to be constantly stirred with an iron spatula until it assumes the appearance of a grayish brown mass, which is to be reduced to powder while hot. This powder is to be put into a phial coated with sand and clay, of which it fills about $\frac{7}{8}$, the phial is to be loosely stopped with clay, put into a crucible and surrounded with sand, and exposed to a red heat. After a time a blue flame will appear at the mouth of the phial and, after it has continued a few minutes, the phial is to be withdrawn, and as soon as practicable closely stopped.

Pyrophorus thus formed is spontaneously inflammable. On exposure to the air, particularly if humid, it takes fire, burns without flame, and exhales the odour of sulphur. If the air be dry, it may be inflamed by breathing upon it. Pyrophorus burns brilliantly in moist oxygen, chlorine, and nitrous gases, and is said to be inflamed by sulphuric and nitric acids. In the formation of this compound the sulphuric acid is decomposed by the carbon and perhaps the hydrogen of the vegetable substance, sulphurous acid is evolved, and sulphur extricated, a portion of which probably combines with the alumina, and a great part of the mass consists of carbon, sulphur, and alumina. But potash appears to be essential to the preparation of pyrophorus, for if the alum contain none of this alkali, the inflammation will not take place. Hence it follows that this substance is necessary to the combustion, and the opinion of Sir H. Davy that the alkali in this process is decomposed, its base liberated, and is the cause of the inflammation, is rendered extremely probable. Pyrophorus, he observes, may be perfectly imitated by a mixture of sulphur, charcoal, and potassium. This idea seems to have been confirmed by the experiments of Dr. Coxe of Philadelphia, who found that by the addition of a few drops of solution of potash to pyrophorus which had lost its power of inflaming, and subsequently heating it, it again acquired that property. I have also ascertained that by mixing a few grains of potash

with the usual ingredients of pyrophorus, its combustible property is always developed.

The uses of alum are numerous and important. It is extensively employed in the art of dyeing as a mordant to fix the colours, and heighten their brilliancy. It is said also to increase the density of tallow, and the adhesive powers of farinaceous pastes. Alum also constitutes an article of the materia medica, being used in medicine as a powerful astringent.

With respect to its composition it may be considered as a compound either of sulphate of alumina, sulphate of potash and water, or of sulphuric acid, alumina, and potash, with water. Vauquelin states the ingredients at 49 parts of super sulphate of alumina, 7 of sulphate of potash, and 44 of water; Berzelius assigns the proportions at 34.23 of sulphuric acid, 10.86 of alumina, 9.81 of potash, and 45 of water; or 36.85 of sulphate of alumina, 18.15 of sulphate of potash, and 45 of water. The latter is probably the most correct.

DXVI. Alumina is of vast importance to society. All the clays are natural mixtures of this substance, with variable proportions of silex, and oxide of iron. The silex always predominates, but the peculiar characters of these mixtures are dependent upon the alumina. Hence it is to be considered as the basis of every species of pottery ware, from the coarsest earthen vessel to the finest oriental porcelain. In the manufacture of porcelain the Chinese employ two articles, the one called Kaolin, the other Petunsé, and both consist of alumina, silex, and lime, the last being in small proportion. The porcelain clay of Europe, which is substituted for one of these, is the product of the decomposition of the feldspar found in a particular species of granite. The peculiar characters of porcelain are probably developed by a semi-vitrification of the materials in consequence of exposure to an intense temperature. The colours delineated upon articles of this kind are

formed of some of the metallic oxides, and they are protected by a coat of transparent enamel.

The uses of the inferior kinds of clay are familiarly known.

SECTION II.

Of Zirconium.

DXVII. This substance has been found in nature only in small quantities. The base combined with oxygen, to which has been given the name of Zirconia, was found by Klaproth in the zircon or jargon, a gem brought from Ceylon ; and it has since been proved to constitute the principal part of the hyacinth. In order to obtain it, zircon in fine powder is to be mixed with 4 or 5 times its weight of potash, and kept in fusion for two or three hours ; the mass is then to be washed with water, to remove the potash ; it is afterwards to be dissolved in muriatic acid, and boiled, by which the silex is deposited. To the filtered liquid is to be added solution of carbonate of soda, not in excess ; a white powder is separated, which is to be collected, dried, and exposed to a red heat.

Zirconia thus procured is a white, insipid, inodorous powder, rough to the feel. The specific gravity is 4.1. It is insoluble in water, but enters into imperfect fusion in the heat of a forge. Before the flame of the oxy-hydrogen blow-pipe it melts into an enamel of such hardness as to scratch rock crystal. Zirconia has an affinity for water, and may be obtained in the form of hydrate by precipitating it from its acid solutions by an alkali, and drying the precipitate by a moderate heat. The water is expelled from it at the temperature of ignition. This hydrate contains about $\frac{1}{3}$ of its weight of water ; it is yellowish, translucent, and bears some resemblance to resin and gum.

Zirconia combines with the acids, but with some difficulty, unless it be in the state of hydrate. Its salts have a sweetish astringent taste, and are not very soluble in water ; they are decomposed by the alkalies and most of the other earths ; and

likewise by a red heat. Their solutions are rendered turbid by sulphuric acid, an insoluble sulphate being formed. Their basis is soluble in an excess of alkaline carbonate.

That zirconia is a compound of a radical with oxygen appears to be proved by the action of potassium. When the vapour of the latter was brought into contact with the former heated to whiteness, it was found by Sir H. Davy that potash was formed and dark particles, which when examined by the microscope, appeared metallic in some parts, and of a chocolate colour in others, were diffused through the potash, and the undecomposed earth.

Zirconia is at present applied to no use.

SECTION III.

Of Glucinum.

DXVIII. In the year 1798 M. Vauquelin, at the request of M. Haüy, undertook the analysis of the two minerals, called Emerald and Beryl, and he found that there existed in both a substance possessed of peculiar properties, but analogous to some of the other earths. To this he gave the name of *Glucina*, from the sweet taste of its saline combinations.

Glucina is obtained from these gems by a complicated process. The beryl or emerald, reduced to fine powder, is fused with thrice its weight of pure potash. The mass is to be diluted with water, dissolved in muriatic acid, and evaporated to dryness. The dry mass is then mixed with a large quantity of water, and filtered. The residue is silex. The salts of glucina and other earths remain in the liquid, and are to be precipitated by solution of carbonate of potash. The precipitate, after being well washed, is to be dissolved in sulphuric acid, to the solution is to be added solution of sulphate of potash, the whole is then to be evaporated to a certain degree, and allowed to remain at rest. Crystals of alum will be deposited, and after they have ceased to be formed the liquid is to be poured off,

solution of carbonate of ammonia in excess is to be added, the whole is filtered and then boiled for some time. The white powder thus formed is to be collected and dried by a red heat. It then constitutes glucina.

Glucina is a perfectly white, insipid, and inodorous powder, insoluble in water, and adherent to the tongue. The specific gravity is 2.96. It is fusible before the oxy-hydrogen blow-pipe. It forms a paste with water, which does not like clay harden or contract by heat.

Glucina is soluble in carbonate of ammonia and forms with it a triple salt, in which property it agrees with zirconia and ittria; it is also dissolved by the other alkaline carbonates.

Glucina combines with the acids and for the most part forms soluble, uncrystallizable salts, which are characterized by a sweet taste. They are decomposed by the fixed alkalies and by ammonia.

There is great reason, says Sir H. Davy, to believe that glucina is a compound of a peculiar metallic substance with oxygen. The evidence that such is its composition, I have obtained, by heating it with potassium in the same manner as alumina; the potassium was for the most part converted into potassa, and dark coloured particles having a metallic appearance were diffused through the mass, which regained the earthy character by being heated in the air, and by the action of water, and in the last case hydrogen was slowly disengaged.

SECTION IV.

Of Ittrium.

DXIX. The Gadolinite, a mineral found at Ytterby in Sweden, was found by Gadolin to contain, besides silica, lime, and iron, a peculiar earth, to which he gave the name of Ittria. It has likewise been proved to constitute a part of a few other native compounds. In order to obtain Ittria, the mineral in fine powder is to be digested for some time in muriatic acid.

The solution is to be evaporated to dryness, the mass redissolved in distilled water, and precipitated by pure ammonia ; the solid substance separated must be digested with solution of potassa ; and the portion which remains is then to be dissolved in muriatic acid not in excess ; into the solution is poured succinate of soda until the precipitation ceases ; the filtered liquid is to be decomposed by carbonate of soda, a white powder will separate, which when collected and dried at a red heat will be Ittria. It may likewise be obtained from the *Ittro-tantalite*, but by a complicated process.

Ittria is in the form of a fine white powder, inodorous, insipid, insoluble in water, though capable of combining with it and of forming a hydrate, containing, according to Klaproth, 31 per cent. of water. In specific gravity it is superior to the earths hitherto mentioned, being 4.84. Mixed with borax it melts before the blow-pipe into a white glass. Alone it is fusible only before the oxy-hydrogen blow-pipe. It is soluble in carbonate of ammonia, but requires a much larger quantity for that purpose than glucina. It is insoluble in the liquid alkalis.

Ittria combines with the acids, and forms salts which have a sweet taste. These salts, or some of them, such as the sulphate and acetate were said to present an amethystine colour ; but Ekeberg affirms that it is owing to the presence of oxides of manganese and iron, and perhaps of cerium. Its affinities for the acids are stronger than those of alumina, glucina, and zirconia. The super-salts of ittria are soluble, such as the sulphate, nitrate, muriate, and acetate ; while those which are neutral are insoluble, as the phosphate, oxalate, carbonate, tartrate, and citrate.

Ittria treated with potassium afforded Sir H. Davy results analogous to those of the other earths ; the potassium was converted into potassa, and the mass presented the appearance of metallic matter. So that the constitution of ittria is probably the same, that is, it may be considered as a metallic oxide.

SECTION V.

Of Thorinum.

DXX. The name of Thorina has been given by Berzelius to an earth, lately discovered by him to exist in some minerals found in Sweden.* These he calls the *deuto-fluate of cerium*, and the *double fluate of cerium and ittria*. Thorina also constitutes a part of the gadolinite.

To obtain it from those minerals which contain protoxide of cerium and ittria, the oxide of iron must first be separated by succinate of soda. When alone in solution, thorina is precipitated by the succinates, but only in minute quantity when mixed with the substances above mentioned. The deutoxide of cerium is then separated by sulphate of potash; after which ittria and thorina are thrown down by caustic ammonia. They are to be dissolved in muriatic acid, and the solution evaporated to dryness, boiling water is to be poured on the residue which will dissolve the greatest part of the ittria; but the undissolved portion still contains a little of it. Dissolve it in muriatic or nitric acid, and evaporate till the solution becomes as neutral as possible; then pour water upon it and boil for an instant. The thorina will be precipitated and the liquid will contain disengaged acid, which, when saturated with ammonia and boiled, will again yield the new earth. Thorina when upon the filter has the appearance of a gelatinous, semi-transparent mass. When washed and dried it becomes white, absorbs carbonic acid, and dissolves with effervescence in acids. Though calcined, it retains its white colour. It dissolves readily in muriatic acid, if the heat to which it has been exposed, have been moderate; but if the heat have been violent it will not dissolve until it has been digested in strong muriatic acid. The solution is yellow, but loses its colour when diluted with water. The neutral solutions of thorina have a taste which is purely as-

* Annals of Philosophy—Translated.—vol. ix. p. 452.

tringent. In this property it differs from all the other earths excepting zirconia.

Thorina does not melt before the blow-pipe. With borax it fuses and forms with it a transparent glass, which, when exposed to the exterior flame becomes opake and milky. With phosphate of soda it melts into a gelatinous mass, but is infusible with soda. When soaked with a solution of cobalt, it becomes grayish brown.

Thorina dissolves in the acids.

With sulphuric acid it forms a salt, capable of being crystallized, but decomposable by water.

It dissolves easily in nitric acid unless it have been previously exposed to a strong heat. The solution does not crystallize, but forms a gelatinous mass, which deliquesces on exposure to the air, and which, when evaporated, leaves a white opake mass similar to enamel, and insoluble in water. A great portion of the thorina is precipitated from this nitric solution by boiling.

Thorina dissolves in muriatic acid in the same way as in the nitric acid. The solution does not crystallize. When evaporated by a moderate heat it is converted into a syrupy mass, which dries in the air and becomes white like enamel, very little soluble in water, and leaving a subsalt. A solution of this earth in nitric or muriatic acid, when evaporated by a strong heat, leaves on the edges of the vessel a white, opake film, having the appearance of enamel. It appears very distinctly when the liquid is made to pass over the inside of the glass. This appearance is regarded by Berzelius as a characteristic mark of thorina, as it belongs to no other substance excepting the solution of phosphate of iron in nitric acid. This earth combines with carbonic acid with avidity. The alkaline carbonates precipitate thorina, combined with the whole of their carbonic acid.

Oxalate of ammonia throws down a white voluminous precipitate, insoluble in water, and in caustic alkalies.

Tartrate of ammonia produces a white precipitate, soluble in caustic ammonia.

Citrate of ammonia occasions no precipitate even after the addition of caustic ammonia ; but thorina separates when the liquid is boiled.

Benzoate of ammonia gives a white precipitate.

Succinate of ammonia precipitates a substance which is immediately redissolved.

Ferruginous prussiate of potash, poured into a solution of this earth, throws down a white precipitate, which is completely soluble in muriatic acid.

According to Berzelius thorina may be distinguished from the other earths by the following properties.

From *alumina* it differs by its insolubility in hydrate of potash ; from *ittria* by its purely astringent taste, without any sweetness, and by the property which its solutions possess of being precipitated by boiling, when they do not contain too great an excess of acid. It differs from *zirconia*, by the following properties. 1. After being heated to redness, it is still capable of being dissolved in acids. 2. Sulphate of potash does not precipitate it from its solutions, while it precipitates zirconia from solutions containing even a considerable excess of acid. 3. It is precipitated by oxalate of ammonia, which is not the case with zirconia. 4. Sulphate of thorina crystallizes readily, while sulphate of zirconia, supposing it free from alkali, forms, when dried, a gelatinous, transparent mass, without any trace of crystallization.

No attempts have been made to decompose thorina, but from the great resemblance in properties to some of the other earths, its composition is no doubt analogous.

It derives its name from *Thor*, an ancient Scandinavian deity.

From what has been remarked it will be perceived, that the real composition of the proper earths, as they have been called, is as yet imperfectly known. There seems to be as much evidence in support of the opinion that their bases are allied to the simple unmetallic radicals, or at least that they form the connecting link between them and the bases of the alkaline

earths, as that they are truly metallic. From this uncertainty we have not attempted to calculate their representative numbers.

DIVISION II.

Of the metals which absorb oxygen from the air, and rapidly decompose water at all temperatures.

SECTION I.

Of Potassium.

DXXI. This curious metal was discovered in the year 1807 by Sir H. Davy. It is obtained by the decomposition of potash, a substance which is procured from the ashes of burnt vegetable matter. When these ashes are washed with water, and the liquid is evaporated to dryness, there remains a solid substance of a grayish white colour, and of a sharp, disagreeable taste. It is the common *potash* of commerce, and is a mixture of carbonate of potash and various other salts, with vegetable matter. After exposure for some hours to a strong red heat, it becomes white with a shade of blue, and then constitutes *pearl-ash*. In this state the potash is still combined with carbonic acid, and in order to be obtained pure it requires to be submitted to other processes. The carbonic acid may be separated in a great measure by the action of quick-lime. A quantity of pearl-ash is to be dissolved in 6 or 8 times its weight of water, and to the solution is added quick-lime recently slaked in the proportion of double the weight of the pearl-ash. The mixture is frequently agitated and allowed to remain for 48 hours, at the end of which, the whole is poured upon a filtre, and the clear solution is to be evaporated until a pellicle appear upon its surface. On cooling it assumes the appearance of a grayish solid, destitute of any crystalline texture. If, when it has acquired the consistence of a syrup, it be poured into cylindrical moulds, it concretes, and these cylinders constitute the *caustic potash* of the surgeons.

In this state however it is far from being pure, and in order to be obtained perfectly free from carbonic acid and foreign salts, it will be necessary to make use of a process first practised by M. Berthollet, which is founded upon the fact of the solubility of pure potash, and the insolubility of its compounds in alcohol or spirit of wine. When the solution of potash above mentioned is evaporated to the consistence of a syrup, a quantity of strong alcohol equal in weight to $\frac{1}{3}$ of the pearl-ash originally employed, is to be added, the mixture is then to be put into a glass vessel, briskly agitated for a short time, afterwards carefully excluded from the air, and allowed to remain at rest for a few hours. The liquid gradually separates into two portions, the lowest consists principally of water holding in solution the foreign salts, while the upper portion, which is of a reddish brown, is composed of alcohol and pure potash. This portion is decanted, and rapidly evaporated in a silver basin to the consistence of a thick syrup; and when this is set aside for a short time, the potash will be deposited in transparent crystals. If the evaporation be continued until a pellicle appear upon the surface, the whole on cooling will concrete into a hard, solid, crystalline mass. It is then to be carefully secluded from the air.

Various other methods have likewise been proposed for obtaining potash. The one practised by Klaproth appears to be very simple; it does not in fact differ in principle from that of Dr. Black, but probably yields a purer product. It consists in boiling equal parts of salt of tartar, (carbonate of potash prepared from cream of tartar,) and carrara marble, or oyster shells burnt to lime, with a sufficient quantity of water, in a polished iron kettle, straining the solution through linen, and again evaporating the solution, though still turbid, until it contain half its weight of potash. It is then filtered a second time, set aside in a glass vessel for some days, and when it has become clear, pouring it off from the sediment.*

* Thomson's Chemistry, vol. i. p. 317. 5th ed.

According to M. M. Gay-Lussac and Thenard, the potash of commerce almost always contains soda, and hence, when decomposed, the product consists of an alloy of potassium and sodium. To obviate this inconvenience, they recommend that the potash should be obtained by projecting a mixture of one part of nitre with two parts of cream of tartar, into an iron basin, or crucible heated sufficiently high to cause a deflagration, or in other words the decomposition of the nitrate of potash. The result is a sub-carbonate of potash, which may be treated in the usual way with lime and alcohol. In fact they affirm that the process by alcohol is not necessary; that it requires only to be heated with quicklime, the solution being evaporated to dryness, afterwards melting the mass in an iron basin, and pouring it off while liquid, by which it will be separated from the carbonate of potash which is precipitated.*

DXXII. Until the year 1807, potash had not been decomposed, and although all reasoning from analogy was in favour of its compound nature, yet chemists were obliged to consider it as an element. Sir H. Davy by the application of voltaic electricity succeeded in obtaining its base, and in demonstrating its properties. "A small piece of potash which had been exposed to the air for a few seconds, so as to give conducting power to its surface, was placed on an insulated disc of platina, connected with the negative end of the battery of the power of 250 of 6 and 4, in a state of intense activity; and a platina wire communicating with the positive end was brought in contact with the upper surface of the alkali; the apparatus was open to the atmosphere." By this arrangement the decomposition of the alkali was produced. No gas appeared at the negative end, but bright metallic globules appeared which soon burned into potash, or were darted to a considerable distance through the air, with bright scintillations.† In subsequent experiments this great chemist by the

* *Recherches Physico-Chimiques*, t. i. 76.

† *Philosophical Transactions* for 1808.

use of oil of naphtha succeeded in preserving a sufficient quantity of this inflammable metal to demonstrate its properties. To this base he gave the appropriate name of *potassium*.

The decomposition of potash by electricity does not require a very high voltaic power. It may be effected by a battery composed of 150 double plates of 4 inches, and the potassium may be preserved in oil of naphtha, or oil of turpentine, by making use of a simple apparatus invented by Mr. Pepys.*

In all cases however, in which the alkali is decomposed in this way, the quantity obtained is very small; but by a method which was soon afterwards practised by M. M. Gay-Lussac and Thenard, much larger quantities of potash may be submitted to experiment, and more of its base procured. It was ascertained by these distinguished chemists that when melted potash was brought into contact with iron heated to whiteness, the affinity of the iron for oxygen was so exalted that the alkali was decomposed and its base disengaged in a state of purity; hence, since this discovery, this method is always resorted to by chemists to procure potassium.

The method of M. M. Gay-Lussac and Thenard consists in passing melted potash, in small quantities at a time, over the surface of clean iron turnings heated to whiteness in a curved gun-barrel. The circumstances necessary to the success of the process, will be found detailed in the *explanation of the plate* at the end of the volume.

DXXIII. Potassium at the temperature of 60° Fah. appears in the form of small globules, possessing the opacity, metallic lustre, and general appearance of quicksilver, so that when globules of each metal are placed near each other, the difference is hardly distinguishable. At this temperature however, it is imperfectly fluid, at 70° it is more liquid, and when heated to 100° its fluidity is perfect, so that two globules when applied to each other readily incorporate. When its temperature is reduced to 50°, it becomes soft and malleable, and its lustre is equal to that of polished silver. At 32° Fah.

* See Plate and explanation.

it acquires hardness and brittleness, and when broken, its fragments exhibit a crystalline texture, which, examined by the microscope, seems composed of beautiful facets of a perfect whiteness, and high metallic splendour. At a temperature little below a red heat, it passes into vapour, and in close vessels may be condensed without alteration.* The fusing point of potassium, according to the experiments of M. M. Gay-Lussac and Thenard is $136\frac{1}{2}^{\circ}$ Fah.† Its specific gravity was at first placed by Sir H. Davy at 0.6, that of water being one; but he has more lately stated it to be between 8 and 9,‡ which coincides with M. M. Gay-Lussac and Thenard's estimate, who state it at 0.865. Potassium is a conductor of caloric and electricity.

DXXIV. The chemical relations of this element are more extraordinary than its physical properties.

When exposed to the air even for a short time, its brilliant surface becomes tarnished, a white crust forms which soon deliquesces, the water thus absorbed is decomposed, and the whole changes to a concentrated solution of potash. When heated nearly to redness in contact with the air, it takes fire, burns brilliantly with a white light and intense heat. From this great disposition to combine with oxygen, potassium requires to be kept immersed in recently distilled naphtha. Introduced into chlorine it takes fire, burns with a bright red light, and forms a chloride of potassium. It also inflames spontaneously in the vapour of iodine, and consumes with a violet coloured flame. Potassium is soluble in hydrogen gas, and it renders that air spontaneously inflammable, its combustion in the atmosphere being frequently accompanied with a beautiful ring, or coronet of smoke, resembling that which is produced by the inflammation of phosphuretted hydrogen. This property however is lost by cooling, the metal being deposited.

* Davy. Philosophical Transactions for 1808.

† *Recherches Physico-Chimiques*, t. i. p. 111.

‡ *Elements of Chemical Philosophy*, Part i. p. 322.

When a mass of potassium is brought into contact with water, a slight explosion is immediately produced, the metal takes fire upon the surface of the liquid, burns with a brilliant and beautiful rose-coloured flame, and gives off hydrogen gas which dissolves a portion of the base and forms potassiuiretted hydrogen. If the potassium be brought into contact with water filling a glass tube, it decomposes it with facility, hydrogen gas is disengaged with much heat and noise, but without the accompaniment of flame.

When placed upon ice the metal immediately inflames and forms a hole which is found at the conclusion of the experiment to be filled with a solution of pure potash. If brought into contact with paper which has been tinged with tincture of turmeric and afterwards moistened with water, potassium takes fire and moves about rapidly, producing at the points of contact a stain of a reddish-brown colour, similar to that which is caused by solid potash.

DXV. Potassium forms no compound with azote; but it decomposes the combinations of azote with oxygen with facility. When heated and plunged into nitrous oxide it burns vividly into potash: it inflames spontaneously in nitric oxide, and upon the surface of nitric acid, in the last case the products being nitric oxide and potash, which immediately combines with the undecomposed acid to form a nitrate.

Immersed in fluo-silicic acid gas, and gently heated, potassium assumes a bluish colour, then burns with flame, the volume of the gas rapidly diminishes, and a chocolate coloured substance is formed, the nature of which has been noticed in **CCLXXXV**. It decomposes vitreous boracic acid when heated together with facility, and disengages its base.

Potassium and phosphorus readily enter into union with each other and the combination is effected by melting them together under the surface of naphtha. It has the colour and lustre of polished lead, and when exposed to the air it is slowly converted into phosphate of potash. The same effect is produced by its active combustion. It would appear that

these substances are capable of uniting in more than one proportion ; for besides the *phosphuret* above mentioned, a compound of a chocolate colour may be formed by phosphorus and potassium, and it is probable therefore that the former consists of 2 proportions of the metal, and the latter of 1 proportion, united in both cases with 1 proportion of phosphorus.* When potassium is melted under naphtha with sulphur, a rapid combination accompanied with heat and light takes place, and a *sulphuret* of potassium formed, which exhibits characters something similar to those of the artificial sulphuret of iron. These phosphurets and sulphurets decompose and are decomposed by water.

When gently heated in sulphurous acid it decomposes it, and is itself converted into potash, the sulphur being deposited. It also decomposes sulphuric acid, and if there be an excess of acid, forms with it sulphate of potash.

It decomposes and corrodes flint and green glass with great rapidity, a fact which may be explained, partly from the great affinity of the potassium for the oxygen of the oxides employed in their composition, and in part from the attraction of pure potash for siliceous matter.

It acts upon the water contained in alcohol and ether, and exhibits nearly the same phenomena as with pure water.

The affinities of potassium are equally energetic and extensive ; “ and in its general powers of chemical combination may be compared with the alkahest or universal solvent imagined by the alchemists.”†

Oxides of Potassium.

DXXVI. Potassium is capable of uniting with different proportions of oxygen, and of forming with it peculiar compounds. There are two well known oxides of this metal, and M. M. Gay-Lussac and Thenard have added a third.

* Davy. Elements of Chem. Phil. p. 329.

† Sir H. Davy.

When potassium wrapped in paper is passed through mercury into a tube containing at the upper part a quantity of water; it immediately acts upon that liquid, produces a brisk effervescence, much hydrogen gas is disengaged, and the water becomes hot and very caustic, at least in cases in which the proportion of the metal employed has been large. From the quantity of hydrogen produced in this experiment, it was concluded by M. M. Gay-Lussac and Thenard, that 100 parts of potassium absorbed 19.945 parts of oxygen; or that 100 parts of the oxide thus formed, contained 83.371 of potassium, and 16.629 of oxygen.*

These results did not correspond precisely with the previous experiments of Sir H. Davy. From the quantity of oxygen which disappeared by the action of a determined weight of potassium, and from the quantity of hydrogen obtained by the decomposition of water by a known weight of this metal, he fixed the proportions at 86.1 of potassium and 13.9 of oxygen.† They were subsequently stated by him to be 83.2 of the base, to 16.8 of the metal. Professor Berzelius arrived at the proportions of the elements in this oxide by subjecting an amalgam of potassium and mercury to the action of water, saturating the oxide with muriatic acid, and determining the amount by the quantity of the salt produced. By this method the proportions were found to be 82.97 of potassium, and 17.03 of oxygen. If the quantity of oxygen in 100 parts of potash be considered as 15, and from the difficulty of arriving at accurate results in such delicate experiments, it will not perhaps be assuming too much, the oxide of potassium produced by the decomposition of water by potassium may be considered as a *protoxide*, and as composed of 1 proportion of oxygen 7.5, and 1 of potassium 42.5, and it will be represented by 50.

When potassium is burnt in oxygen gas in a tray of platinum, covered with a coating of *muriate of potash*, it is converted

* *Rechères Physico-Chimiques*, t. i. p. 117.

† *Philosophical Transactions for 1808*.

into a substance of an orange-yellow colour, fusible, but less so than common potash, and crystallizable in laminæ. Brought into contact with water, it produced a brisk effervescence, and an elastic fluid was given off, which was proved by M. M. Gay-Lussac and Thenard to be oxygen gas.* When melted and brought into contact with combustible bodies, oxygen is transferred from it with so much rapidity as to occasion in the latter the phænomena of active combustion. Heated in carbonic acid, oxygen is expelled, and sub-carbonate of potash formed. Exposed to a strong heat, oxygen gas passes off, and there remains behind a difficultly fusible substance of a gray colour, vitreous in its fracture, soluble in water without effervescence, but with much heat, and forming an alkaline solution. This substance is the protoxide or pure *dry* potash, and it was first obtained by Sir H. Davy.† The results of the experiments made by M. M. Gay-Lussac and Thenard to ascertain the proportion of the elements to each other in this oxide do not perfectly accord. The conclusion may be drawn from them, that it contains at least twice as much oxygen as is found to exist in potash, and may be considered as composed of 2 proportions of oxygen 15, and 1 of potassium 42.5; its representative number will therefore be 57.5. It is the *peroxide*.

If potassium be put into a phial filled with atmospheric air, and partially closed by a cork, it becomes changed in a short time to a substance of a bluish-gray colour, brittle, fusible at a very moderate temperature, and so inflammable that it will often take fire on exposure to the air, and always in oxygen gas when heated to a temperature between 68° and 77° Fah. When thrown into water it decomposes the liquid with effervescence, but less violently than an equal weight of pure potassium.‡

* *Rechères*, t. i. p. 136.

† *Elements of Chemical Philosophy* Part 1. p. 323.

‡ Gay-Lussac and Thenard—*Rechères*. t. i. p. 127.

This substance was considered by the French chemists as a protoxide of potassium ; but this opinion does not appear to have been established, for by other chemists it is regarded as a mixture of potash and potassium. If it be of uniform composition, it is most probably an oxide consisting of 1 proportion of oxygen, and 2 proportions of potassium.

The oxide produced by the decomposition of water by potassium, or by exposing the peroxide to a strong heat, is the substance which is known by the name of potash ; in the last case being dry, and in the first combined with water.

Potash.

DXCVII. This substance, when obtained from its alcoholic solution, is in the form of white and pearly crystals, of some hardness, which have a sharp, disagreeable, urinous taste, and act upon the skin as a violent caustic. It combines with oils and forms with them saponaceous compounds, converts vegetable blues to a green, and gives to turmeric a dark brown colour. It unites with the acids and forms peculiar salts, and by fusion with silex, constitutes glass. It is volatilized at a full red heat. On exposure to the air, potash rapidly attracts its aqueous vapour, deliquesces, and becomes liquid. It is very soluble in water, dissolves in it with rapidity, and if crystallized reduces the temperature, but when it has been previously melted and cooled causes an increase of heat. Exposed to heat it becomes liquid, and then gives off abundance of aqueous vapour, for its crystals are said to contain no less than 53 per cent. of water. But the attraction of potash for water is so strong, that no method has yet been discovered of obtaining it perfectly dry, except by heating the peroxide ; by acting on potassium with a quantity of water, the oxygen of which is just sufficient to convert the metal into potash ; or by heating potassium with common potash. That potash even after having been exposed for a long time to a red heat contains water, is proved by the fact that in the

process for procuring its base, large bulks of hydrogen gas are evolved ; and Sir H. Davy found that when heated with boracic acid 100 parts of it gave off between 17 and 18 parts of water. The amount of the water chemically combined with potash by so powerful an attraction, has been variously stated by different chemists. According to M. Berthollet, 100 parts contain 13.5 parts of water ; Berzelius makes it amount to 16.15 ; and Sir H. Davy to from 17 to 19 parts ; while by M. M. Gay-Lussac and Thenard it is estimated at $\frac{1}{3}$ the weight of the solid. This hydrate may be considered as composed of 1 proportion each of potash and water, and may be represented by $50 + 8.5$, or 58.5 .

The question, however, in what mode the elements of this water exist in hydrated potash, has not been decided. If the hypothesis of Dr. Murray be adopted, this substance must be considered as composed of potassium, oxygen, and hydrogen, and when acted upon by an acid, it must be presumed that the excess of oxygen enters into combination with the hydrogen, in the proportion necessary to constitute water, and is evolved.

Chloride of Potassium.

DXXVIII. When thin pieces of potassium are introduced into dry chlorine, the metal takes fire spontaneously, and burns with a vivid light ; the gas is rapidly absorbed, and a white substance is formed which has all the properties of the salt, well known by the name of *muriate of potash*. The attraction of potassium for chlorine is very powerful, for it separates that element from hydrogen and phosphorus with the phenomena of combustion ; and it decomposes chloride of sulphur with explosion. Chlorine displaces oxygen from its combination with potassium, for when it acts upon potash, or the orange-coloured oxide, it disappears and oxygen gas is disengaged.*

The chloride of potassium may be formed by dissolving potash in muriatic acid. In this case there is a double de-

* Sir H. Davy. Elements, p. 327.

composition ; for the oxygen of the alkali combines with the hydrogen of the acid, forming water, while the potassium of the former and the chlorine of the latter unite, and constitute a binary compound. When the solution is sufficiently evaporated, there forms on cooling a salt crystallized in small cubes, of a bitter, disagreeable taste, permanent in the air, and soluble in 3 parts of water at 60° , and in a smaller proportion at 212° . When exposed to heat it decrepitates in consequence of losing its water of crystallization, but suffers no decomposition even at the temperature of ignition

According to the experiments of Sir H. Davy, it is composed of 52.8 of potassium and 47.2 of chlorine ; and these results correspond very nearly with those of M. Gay-Lussac, who has found that in this compound the elements are in the ratio of 28.924 of chlorine, to 32.196 of potassium ; or 47.33 of the former to 52.67 of the latter. It is a compound of 1 proportion of each, and may be represented by $42.5 + 33.5$, or 76.

On the other hand, if this salt be a compound of muriatic acid and potash, it will consist, according to Dr. Wollaston, of 36.59 parts of the acid, and 63.43 of the base.

Salts of Potash.

DXXIX. 1. *Chlorate, or hyper-oxy-muriate of potash.* The properties and modes of formation of this salt are very curious and interesting. It appears to have been first analyzed and accurately described by M. Berthollet, and it was afterwards submitted to a rigid examination by Mr. Chenevix. The only method by which it could be formed was by transmitting a stream of chlorine through a solution of potash, until M. Gay-Lussac obtained chloric acid and formed the salt by a direct combination of its proximate elements.*

But as this acid is not easily procured in large quantities, the process for preparing it consists in dissolving about 1 part

* Memoir on Iodine—Annals of Philosophy, vol. vi. p. 129.

of pearl-ash in 6 parts of water, putting the solution into the second bottle of Woulf's apparatus, a small quantity of water being in the first, and transmitting through it chlorine gas, until the liquid is saturated. During the mutual action of the materials carbonic acid is evolved, and a slight effervescence produced. As the saturation proceeds, small, flat, and shining crystals are deposited; and Dr. Thomson affirms that in order to obtain these crystals it is necessary that the bottle containing the solution should be secluded from light.* The actions which take place in the production of chlorate of potash, are rather complicated and obscure. At the end of the operation, the vessel which holds the alkaline solution is found to contain two salts, one of them being chlorate of potash, and the other chloride of potassium; the greater part of the former is deposited in the solid form, but the whole of the latter remains in solution. If chlorine be a simple substance, it must be inferred that one portion of the potash is decomposed, its oxygen is evolved and the potassium, combining with chlorine, forms the chloride of potassium, while the oxygen unites with another portion of chlorine, constituting chloric acid which then enters into combination with the undecomposed potash, and produces the chlorate; but as this acid contains 5 proportions of oxygen, it is not improbable that part of its oxygen may be obtained by the decomposition of water. The salt, after the operation is completed, is to be collected, and dissolved in boiling water, and it will be deposited as the solution cools; or it may be obtained by the evaporation of a portion of the water.

It is usually in the form of hexagonal plates of a silvery lustre, and of a cooling saline taste. By care it may be obtained in regular obtuse rhomboidal prisms. It is soluble in water, requiring for its solution 16 parts at the temperature of 60° , and $2\frac{1}{2}$ parts at 212° . It is permanent in the air. On exposure to heat it melts into a transparent liquid, and if the temperature be raised nearly to ignition it is decomposed,

* System of Chemistry, vol. ii. p. 220. 5th ed.

and its only products are aqueous vapour, and pure oxygen gas, the last of which amounts to rather more than $\frac{1}{3}$ of the salt employed. The residue in the retort is chloride of potassium.

From the great quantity of oxygen contained in this salt, and the looseness of the affinity by which it is retained to the other elements, it is decomposed with great energy by combustible substances, and explosions are commonly produced. Mixed with sulphur in the proportion of 3 to 1, and triturated in a mortar, successive and loud detonations will be produced; and this effect will take place simultaneously in the whole mass, if after intimate mixture it be collected in a heap and be struck forcibly with the pestle, or with a hammer on an anvil. When about half a grain of phosphorus is covered with this salt and subjected to percussion, a loud explosion takes place, and ignited sparks of the phosphorus are thrown to a considerable distance. This is not therefore a safe experiment; nor that of producing the appearance of fire under water, by pouring strong sulphuric acid into a vessel of water which contains a few grains of chlorate of potash and phosphorus. A flame may be readily obtained by moistening a piece of paper with spirit of turpentine, placing upon it a grain or two of this salt, and touching it with a drop of sulphuric acid. The same effect may be produced by mixing about equal weights of chlorate of potash and sugar, or flour in fine powder, and adding to it a drop of the same acid. This easy decomposition has been made use of for the production of light. A mixture of 2 parts of chlorate of potash and 1 of sulphur is made to adhere to a common sulphur match by means of a solution of gum, and this when moistened with sulphuric acid immediately takes fire. The matches, together with a small phial containing cotton, or amianthus wet with sulphuric acid, are put up in japanned cases, and sold in the shops. A necessary precaution to be observed in the preparation of these matches is to powder the materials separately, as fatal accidents have arisen from inattention to this

circumstance. The disposition to decomposition and explosion is great, and almost certainly happens when these substances in their dry state are exposed to friction; it has even been said that it is dangerous to keep the salt in contact for a time with any combustible substance.

In the year 1788 experiments were made at Essone in France, to substitute this salt for nitre in the manufacture of gun-powder, but their termination was unfortunate, for during the trituration of the materials a violent explosion was produced, which was fatal to two of the persons engaged in the operation.

Decrepitations or explosions are likewise produced when chlorate of potash is rubbed or exposed to friction with cotton, and many of the metals; and when nitric acid is poured upon a mixture of this salt and phosphorus, flakes of fire are emitted at intervals for a considerable time.*

The mode by which these explosions are produced appears to be sufficiently obvious. The chloric acid is decomposed by the combustible body, oxygen is transferred with great rapidity from the former to the latter, and the concussion is produced by the formation either of permanently elastic fluids, or vapours, the expansive energy of which is greatly augmented by the high temperature accompanying the decomposition.

From the experiments of M. Gay-Lussac it appears, that 100 parts of this salt yield, on exposure to heat, 38.88 parts of oxygen, and that the residue is a chloride of potassium, composed of 28.924 of chlorine, and 32.196 of the metal. Now if 6.576 be subtracted from 38.88 for the quantity of oxygen contained in the potash, we shall have 32.304 for the oxygen existing in the chloric acid; and this quantity must have been combined with 28.924 of chlorine;† so that the composition of chlorate of potash may be stated as follows.

* Thomson's Chemistry, vol. ii. p. 221, 5th ed.

† Memoir on Iodine—Annals of Philosophy.

	Prop.	Atoms.	
Chloric acid	1	1	61.228
Potash	1	1	38.772
			<hr/> 100.000

Its representative number will be $72 + 50 = 122$.

The analysis of this salt by Berzelius very nearly accords with that of M. Gay-Lussac.*

Perchlorate of potash. The properties of this salt have been described, vol. i. p. 254.

Iodate of potash. This salt may be obtained by dissolving iodine in a solution of pure potash, from which it is precipitated in the form of a white powder, containing hydriodate of potash, which may be removed by alcohol. It is a white crystalline salt, soluble in about 13 parts of water at the temperature of 57° ; it is permanent in the air, and decomposable by heat giving off oxygen, and leaving iodide of potassium. It deflagrates when heated sufficiently in contact with combustible bodies. Its proximate elements exist in it in the proportion of about 100 of iodic acid to 29 of potash.

Fluate of potash. The combination of pure potash in solution with fluoric acid is rapid and produces much heat. The resulting salt is very deliquescent, crystallizes with difficulty, and has a sharp taste. It is decomposed by sulphuric acid, and the fluoric acid is disengaged in the form of vapour.†

Hydriodate of potash may be formed by saturating hydriodic acid with potash. It is very soluble in water, requiring, according to Gay-Lussac, only about $\frac{2}{3}$ its weight of that liquid at 65° . On attempting to procure it in a solid form it is decomposed, the hydrogen of the acid uniting as he supposes with the oxygen of the potash, and forming water, while the iodine of the former, and the potassium of the latter combine, and constitute an iodide. It consists of 100 of the acid, and 37.43 of potash.

* Annales de Chimie, LXXX, p. 27.

† Gay-Lussac and Thenard. Recherches Physico-Chimiques, t. ii. p. 21.

DXXX. Nitrate of Potash. This is one of the most important of the salts of potash. It is a native production, and is found mixed with soil in various parts of the earth. It is procured in great quantities in Bengal, and it has been found in abundance in the immense caves of Kentucky in the United States. The nitre is obtained from the soil in which it is formed by lixiviation, and subsequent crystallization. But the consumption of this salt is so great that enough is not formed in this way to supply the demand, and recourse has been had in Europe to *artificial nitre beds*, as they have been called. The method of producing it appears to have been particularly investigated in France during the revolution, when its external commerce was destroyed.

These beds are formed of the refuse of animal and vegetable matter, mixed with carbonate of lime; they are protected from rain by roofs, but are freely exposed to the air, in which state they are allowed to remain for some months, being occasionally turned in order to expose the whole mass successively to the atmosphere. In the course of time nitrates of potash and lime are formed, which are washed from the mass by water. The solution is afterwards evaporated until the nitre, which is less soluble than the other salt, shall be deposited on cooling. In this state it constitutes *crude nitre*. It is afterwards refined by subsequent solution and crystallization.

The theory of the process by which this salt is formed is not yet completely established. It is known that while animal matters are decomposing they give out nitrogen; this, in its nascent state, probably combines with atmospheric oxygen, and produces nitric acid, which then unites with the lime and potash present in the mass. But in order to form nitre in this way it is absolutely necessary that lime, in the state of carbonate, should be one of the ingredients of the beds. Neither pure lime, nor the two fixed alkalies will answer the same purpose, probably because they act with too much rapidity upon the putrescent mass. It has been observed that nitre is formed spontaneously in those places which are open to the

air, and in which carbonate of lime and some animal matter are present. Hence it frequently appears upon the walls &c. of buildings where moisture is present. But Chaptal obtained nitre from a mixture of bullock's blood and carbonate of lime alone; and it is difficult to trace the source of the potash in this experiment.

Nitrate of potash in its pure state is crystallized in the form of a six-sided prism terminated by six-sided pyramids, the primitive form of which, according to Haüy, is a rectangular octoedron. It is likewise seen in the figure of the dodecaedron, and in that of a table. Its taste is cool but penetrating; it is soluble in 7 parts of water at 60° , and in an equal part at 212° ; so that it is deposited from its saturated solution as it cools, and when this is slowly produced long and beautiful prisms are frequently formed even in the small way. Kirwan affirms that it is soluble in 100 parts of alcohol of the specific gravity of 0.878; but if it be stronger it does not take up any of the salt.

When heated strongly, but considerably below a red heat, it melts into a transparent liquid, which becomes a crystalline solid on cooling. If the temperature be nearly raised to ignition the nitric acid is decomposed, oxygen gas disengaged, and the salt is converted into a *nitrite*. If the heat be augmented, the acid in this salt will likewise be decomposed, oxygen and nitrogen gases will pass off, and potash alone will remain. Nitre is sometimes employed to procure oxygen gas, and in this case it is to be remembered that the portion which first comes over is the purest, as has been proved by Mr. Dalton; for on decomposing nitre by heat, and examining the air caught at different periods of the experiment, he found the first to contain 70, and the last only 50 per cent. of oxygen. The quantity of air given out by this decomposition is very considerable. From 1 ounce of the salt M. Berthollet obtained from 550 to 580 cubic inches; Cavallo made it amount to 750 cubic inches; and Ehrman from 7 to 800 cubic inches, composed of oxygen and azote.

From the quantity of nitric acid contained in this salt, and the facility with which it may be decomposed, it operates with great energy when heated in contact with combustible bodies. When mixed with charcoal or sulphur and projected into a red hot crucible, it is decomposed, oxygen is transferred to the inflammable substance, and the combustion is vivid, attended by a peculiar hissing noise. When struck forcibly on an anvil with phosphorus it explodes with a loud report. When deflagrated with 3 parts of tartar, the result is potash mixed with charcoal. It then constitutes the *black flux* of mineralogists. The *white flux* is formed by using equal parts of nitre and crude tartar.

Nitre is likewise an essential, as well as the largest ingredient in gunpowder. This mixture is composed of 75 or 76 parts of nitre, 15 or 16 of charcoal, and 9 or 10 of sulphur. Next to the proportions, the greatest object is to form the most intimate mixture of the ingredients. This is done by reducing them separately to impalpable powders, and afterwards incorporating them by means of water. The mixture is then granulated, glazed, and dried.

When gunpowder inflames the nitre is decomposed by the sulphur and charcoal, and there is a simultaneous production of sulphurous acid, carbonic acid, nitrogen, and nitric oxide gases. The solid, which remains, consists of sulphuret and carbonate of potash, with a small proportion of charcoal. The production of the gases may be shown by a simple and satisfactory experiment. Fill a tube of brass of a convenient size with gunpowder sufficiently moistened to allow of its being formed into a mass, inflame it, and plunge the mouth of it under a tall jar filled with water, and inverted upon the shelf of a common water trough. As the powder burns large bulks of air will pass into the vessel. When it has become clear, introduce into it a little atmospheric air or oxygen gas, and the red colour of the nitrous acid gas will immediately appear. The presence of the other gases may be ascertained by appropriate tests. This formation of elastic fluid accounts suf-

ficiently well for the explosion of gunpowder. When a spark from the collision of flint and steel falls upon a mass, it heats the particle of nitre, and probably a particle of sulphur or charcoal upon which it rests sufficiently high to cause the latter to decompose the former, oxygen is rapidly transferred from the salt to the combustible, and the temperature thus produced occasions the decomposition of contiguous particles, and so rapidly as to seem a simultaneous combustion ; large bulks of air are suddenly formed, and their elasticity being greatly augmented by the heat, they produce a violent concussion in the air. That the heat of the gases has a great effect in occasioning the explosion, has been proved by Count Rumford, for when gunpowder was fired in an apparatus capable of withstanding the explosion, and the gases were confined for a few minutes, or even seconds, their expansive power when allowed to act was found to be exceedingly diminished, nay almost insensible.* From this experiment and others the Count drew the conclusion that the force of gunpowder depended upon the sudden production of steam or aqueous vapour.† But this cannot be the case, because neither nitre nor either of the other ingredients contains water.

The expansive force of gunpowder has been variously estimated ; by Mr. Robins it was inferred to be equal to 1000 atmospheres, or to 15000 pounds on a square inch ; by Daniel Bernouilli, to 10,000 atmospheres, or 150,000 pounds ; by Dr. Hutton to 2000 atmospheres, or 30,000 pounds ; and by Count Rumford to 50,000 atmospheres, or 750,000 pounds. The estimate of the last is thought to be much too high ; its force is probably between the calculations of Bernouilli and Dr. Hutton.

A compound analogous to gunpowder and commonly known by the name of *pulvis fulminans*, is prepared of 3 parts of nitre, 2 of salt of tartar or carbonate of potash, and 1 of sulphur. Twenty or thirty grains of this powder when heated

* Nicholson's Journal, vol. i. 4to. p. 464.

† Ibid. 518.

on an iron plate enter into fusion, become brown, and then suddenly explode with a loud report. On exposure to heat a sulphuret of potash is formed, sulphuretted hydrogen is then probably produced, which combining with the oxygen expelled from the nitre, produces sulphurous acid gas and aqueous vapour, the elasticity of which is much increased by the high temperature. The extrication of carbonic acid likewise increases the explosion.*

Signal lights are formed of nitre, sulphur, and sulphuret of antimony, or of arsenic.

The proportion of the proximate elements of nitrate of potash has been variously stated. The following table presents the results of the analyses of the most eminent chemists.

Acid	41.30†	40.50‡	46.70§	51.36	53.80¶
Base	58.70	59.50	53.30	49.64	46.70
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00

Nitrite of potash. This name is applied to nitre after it has been exposed to a red heat and has given off oxygen. It is doubtful however whether a true nitrous acid exists, and as the mass is alkaline, it may be inferred that only a part of the nitric acid is decomposed in this experiment, the remainder, with a portion of nitric oxide, being combined with the potash.

DXXXI. *Carbonate of potash.* It has been long known that potash is capable of combining with carbonic acid in more than one proportion; but it was first ascertained by Dr. Wollaston that one compound contains just twice as much acid as the other; or in other words that the proportion in one is a multiple of that in the other. There are two salts which are carbonates; in the first the properties of the potash predominate, while in the second they are nearly neu-

* Murray's System of Chemistry, vol. ii. p. 591, 4th ed.

† Berthollet. ‡ Thenard. § Richter. || Berard. ¶ Wollaston.

tralized. To the former is applied the name of *carbonate* or *sub-carbonate*; to the latter that of *bi-carbonate*.

1. *Sub-carbonate*. The pearlash of commerce is a sub-carbonate of potash, but not in a state of purity. It may be prepared by dissolving pearlash, after having been exposed for some time to ignition, in water, filtering the solution and evaporating it in a metallic basin until a pellicle appear upon the surface. By resting for a few hours, the foreign salts will be deposited; the clear liquid is then to be decanted and evaporated to dryness. This salt may also be obtained by exposing to a red heat the substance called *tartar*, or the super-tartrate of potash; or the bi-carbonate of potash.

Carbonate of potash is in the form of a white granular mass, which is not susceptible of crystallization. Its taste is acrid and urinous, it gives a green tinge to vegetable blues, combines with oils, and forms soapy compounds, and effervesces with all the acids. It is deliquescent, and on exposure to the air attracts its aqueous vapour and becomes liquid. It is very soluble in water, requiring about its own weight at 60°. From the mean of the experiments of different chemists the composition of carbonate of potash may be stated as follows.

	Prop.			Atoms.			
Carbonic acid	1	-	-	1	-	-	30
Potash - - -	1	-	-	1	-	-	70
	<hr/>			<hr/>			<hr/>
	2			2			100

It may be represented by $20.7 + 50 = 70.7$.

2. *Bi-carbonate*. When a saturated solution of the carbonate of potash is exposed to the air for some months, it attracts carbonic acid, and forms a solid crystallized salt. It may be formed in a much shorter time by placing the vessel containing a solution of the carbonate in the fermenting vat of a brewery, or distillery. A still shorter method of obtaining the bi-carbonate, is to put a solution of one part of pearlash in 3 parts of water, into the middle part of Nooth's

apparatus, and to pass through it a stream of carbonic acid, until it is saturated; the deposition of crystals then commences, and when finished they are to be collected and dried without the application of heat. During this saturation a small quantity of silica is always deposited.

Bi-carbonate of potash is in the form of quadrangular prisms more or less bevelled. Its taste is slightly alkaline, but not acrid, and it changes vegetable blues to a green. It does not attract moisture on exposure to the air. In cold water it is soluble in about 6 times its weight, and in rather more than its own weight at 212° . On exposure to heat it gives off a quantity of water and carbonic acid, and is converted into the carbonate of potash.

It appears by the experiments of Dr. Wollaston that bi-carbonate of potash contains twice as much carbonic acid as the sub-carbonate. It is therefore composed of

	Prop.			Atoms.			
Carbonic acid	2	-	-	2	-	-	45.46
Potash	1	-	-	1	-	-	54.54
	<hr/> 3			<hr/> 3			<hr/> 100.00

The dry salt will therefore be represented by $41.5 + 50 = 91.5$; but as it contains 1 proportion of water, the number will be $91.5 + 8.5$.

Potash may be supersaturated with carbonic acid by dissolving an ounce of the sub-carbonate in 8 or 10 pounds of water, and passing carbonic acid through it in Nooth's or Woulf's apparatus. It acquires a pungent acidulous taste, similar to that of *soda water*, and is applied to the same uses in medicine.

Phosphate of potash. Potash combines with phosphoric acid, according to Dr. Thomson, in three proportions, forming the *phosphate*, *bi-phosphate*, and *sub-phosphate*.

1. *Phosphate.* It is obtained by adding carbonate of potash to hot phosphoric acid till the solution ceases to produce

any effect on vegetable blues. When sufficiently concentrated it gradually deposits small transparent crystals in the form of 4 sided prisms, terminated by 4 sided pyramids, of a cooling, somewhat urinous taste; they are permanent in the air, soluble in water, and become liquid at a red heat. It is composed of phosphoric acid 100, potash 133.5.

2. *Bi-phosphate*. Prepared by dissolving the above salt in phosphoric acid till the liquid is saturated. The solution is gelatinous, and yields a sparing product of striated crystals, extremely soluble in water, deliquescent in the air, and convertible into a vitreous deliquescent substance at the temperature of ignition.

3. *Sub-phosphate*. Formed by mixing together phosphate of potash and pure potash, and exposing the mixture to a strong heat in a crucible of platina; or by boiling an alkaline super-phosphate with potash. This salt is white, insipid, insoluble in cold, but soluble in hot water, from which it is precipitated as the solution cools, in the form of a gritty powder. It is fusible before the blow-pipe into a transparent bead, opaque when cold. It is soluble in nitric, muriatic, and phosphoric acids. Composed of acid 100, potash 266.5.

Hypo-phosphite of potash. Formed by direct combination. Very soluble in water and alcohol; deliquescent; absorbs oxygen from the air, and becomes acid; and when heated gives off phosphuretted hydrogen gas, and phosphorus, the residue consisting of phosphoric acid and potash.*

Sulphate of potash. This salt which, under the name of *vitriolated tartar*, has been known for many years, may be formed by the direct combination of its proximate elements; but is usually prepared more economically by making a solution of the salt which remains after the distillation of nitre with sulphuric acid, in the process for obtaining nitric acid, adding to it carbonate of potash until all effervescence ceases, and evaporating the liquid to a certain extent. It is usually crystallized in the form of hexaedral pyramids, or short

* Thomson's System of Chemistry, vol. ii. pp. 421—423. 5th ed.

6 sided prisms terminated by 6 sided pyramids. Its taste is saline and bitter ; it is soluble in 16 times its weight of water at 60°, and 5 times its weight at 212°. Sulphate of potash suffers no change on exposure to the air, nor is it decomposed by a red heat, though it may be fused. It is sometimes phosphorescent in the dark. It is composed of about 45.72 of acid, and 54.28 of potash.

Bi-sulphate of potash. Prepared by exposing to heat in a glass vessel 3 parts of sulphate of potash with 1 of sulphuric acid ; the mass first melts and exhales vapours ; on allowing it to cool it concretes into a crystalline body, which, if dissolved in water and slowly evaporated, forms prismatic crystals, of an acid taste, capable of reddening vegetable blues, and more fusible and soluble than the neutral sulphate, but not deliquescent. It contains twice as much sulphuric acid as the neutral sulphate.

Sulphite of potash. When sulphurous acid gas is transmitted through a saturated solution of carbonate of potash, carbonic acid is disengaged, the solution becomes hot, and as it cools sulphite of potash is deposited. It is in the form of rhomboidal plates, or small white and transparent needles, of a penetrating and sulphurous taste, very soluble in water, and decomposable by most of the acids. Exposed to the air it is slightly efflorescent, and is slowly converted into sulphate of potash, in consequence of absorbing oxygen. It decrepitates on exposure to a strong heat, and is then decomposed, sulphurous acid is evolved, sulphur separates, and the residue is sulphate of potash. It is composed of 40 of sulphurous acid, and 60 of potash.

Prussiate or hydrocyanate of potash. When potassium is heated in vapour of hydro-cyanic acid, there is absorption without inflammation, and the metal is converted into a gray spongy mass, which melts, and assumes a yellow colour. The hydrogen of the acid is disengaged. This compound then

is to be considered as a cyanide of potassium.* When thrown into water it dissolves without effervescence, and the water is inferred by M. Gay-Lussac to be decomposed, its oxygen being transferred to the potassium, and its hydrogen to the cyanogen ; so that the result will be hydro-cyanate of potash.

The hydro-cyanates were first formed and examined by Scheele. The properties of the bases are not completely neutralized, the salts have little permanency, and can be applied to few or no uses. The prussiates employed by the chemists are all triple compounds of hydro-cyanic acid, alkaline or earthy bases, and iron ; or according to Mr. Porrett's view of their constitution, binary compounds of ferro-cyanic acid and bases.

Ferro-cyanate of potash, or ferruretted chyzate of potash: This is the important salt, which has been until lately termed triple prussiate of potash. It has been extensively employed as a test to discover the presence of iron, with which it forms precipitates varying in colour, as it operates upon the protoxide, or peroxide of that metal. But as the salt itself contains iron, an uncertainty has existed in using it, because if any acid be present in the liquid into which its solution is poured, that acid will decompose it, and occasion the formation of prussian blue. And even where iron exists, the proportion may be erroneously stated, from the circumstance that the iron in the triple prussiate itself contributes to augment the quantity of prussian blue precipitated. But the recent investigations of Mr. Porrett and of M. Gay-Lussac will do away the last of these objections, for supposing the salt to be of uniform composition, and there is no reason why it should not be so considered, it was only necessary to ascertain the proportion of iron essential to its constitution, to enable the experimenter to make the necessary allowance. Analyses for this purpose have been made by Richter, Bucholtz, Proust, and Porrett. The last of these chemists,

* Gay-Lussac. Memoir on Prussic acid—Translated—Annals of Philosophy, vols. vii. & viii.

whose examination was apparently conducted with great accuracy, states the composition of ferro-cyanate as follows.*

Prussic acid	-	-	-	30.40
Potash	-	-	-	39.34
Black oxide of iron	-	-	-	17.26
Water	-	-	-	13.00
				<hr/>
				100.00

Various processes for the preparation of this salt have been proposed and practised. One of the most simple is that of Bucholz, which consists in mixing 2 parts of dried blood with 1 of carbonate of potash, and heating them in a crucible at the temperature of ignition for three quarters of an hour after the flame, which always appears on exposure to heat, has ceased. The mass is then dissolved in water, the solution is filtered, and evaporated to a sufficient degree. Dr. Henry has likewise given directions for the preparation of this salt in a state of great purity.†

Ferro-cyanate of potash is in the form of transparent crystals of a fine yellow colour, the figures of which are cubes or parallelopipeds. Its taste is alkaline; it is inodorous, and heavier than water. Submitted to heat it is decomposed, gives off hydro-cyanic acid and ammonia, and leaves a residue of charcoal, oxide of iron, and potash. It is not acted upon by the acids at common temperatures, but is decomposed when boiled with them. Its solution decomposes metallic solutions, and forms precipitates, which are either cyanides or hydro-cyanates.

Potash with Silica.

DXXXII. These two substances seem capable of uniting with each other in all proportions. The combination is effect-

* Philosophical Transactions for 1814.

† Nicholson's Journal, 4to. vol. iv. pp. 30, 171. Elements of Chemistry, 7th ed. Am. p. 307.

ed by fusion, and the properties of the compound are dependent upon the proportions of the constituents; its softness is dependent upon the excess of the potash over the silica. When 3 parts of the former are mixed with 1 of the latter, both being in fine powder, and the mixture is exposed to a full red heat, they soon melt and a considerable effervescence takes place from the disengagement of aqueous vapour, and of carbonic acid, if the carbonate have been employed. The result is a vitreous mass, which, on exposure to the air, deliquesces, and becomes liquid, and which is soluble in water. By the affusion of hot water the greatest portion is dissolved. When this solution is filtered, and a portion of its water is evaporated, it constitutes the old *liquor silicum* of the earlier chemists, the *silicated potash* of the moderns. It is a dense oily-like liquid, transparent, of a strong alkaline taste, for the potash exists in it in excess. It is decomposed by the acids which combine with the potash, and precipitate the silica; when concentrated it is converted into a solid by the addition of concentrated sulphuric acid; for the sulphate of potash formed absorbs the water, in which the silicated potash was previously dissolved. It is likewise decomposed by water alone when large quantities of the latter are employed. When this solution is allowed to stand for a long time, it deposits crystals of silica, as has been stated, vol. i. p. 362.

In proportion as the excess of alkali is diminished, the compound becomes less deliquescent and soluble, and when about 2 parts of silica to 1 of potash are employed, the product when cool is transparent, brittle, insoluble in water, and incapable of being acted upon by any of the acids with the exception of the fluoric. It then constitutes glass.

Phosphuret of Potash.

DXXXIII. When phosphorus is boiled in a strong solution of potash, it produces phosphuretted hydrogen gas; it is probable that a phosphuret of potash is first formed, which then

decomposes the water. The compound of the two substances has been procured in a solid form by the Chevalier Simentini.* The process was as follows.

Into a saturated solution of pure potash in very strong alcohol, small pieces of phosphorus were introduced, which, when dissolved, were placed by others, until the disengagement of gas ceased and the phosphorus remained unchanged. This occupied about 15 days. At the bottom of the vessel there were found scales of a certain brilliancy, and a powder of a dark red colour. The liquid when filtered appeared as fluid as water, of a straw yellow colour, and of a sharp sweetish taste. The scales upon the filtre were dissolved in pure water, which when filtered was clear and limpid. These solutions when evaporated to the consistence of syrup, yielded confused and not permanent crystals; evaporated to dryness they afforded phosphuret of potash, of the appearance of a white opake mass, which when strongly heated, took fire and burned with a yellow flame, leaving behind a gray mass semi-liquid and deliquescent. The scales above mentioned are a phosphuret; they are deliquescent, and when heated they burn with a white flame. The solutions of this phosphuret are decomposed by the acids. When nitric acid is added, nitrate of potash is formed which speedily crystallizes. If the mixture of the liquid and the salt be heated until it be dry, a violent explosion will take place. The detonation is so great that it is thought to be inferior only to that of fulminating silver. The experiment therefore must be made only upon very small quantities.

The process for preparing the phosphuret was afterwards simplified. Form a saturated solution of potash in water; add pieces of phosphorus; no action will take place, but when highly rectified alcohol is added, a lively effervescence immediately takes place, and proto-phosphuretted hydrogen gas is liberated in abundance. The solution is afterwards to be evaporated.

* *Annals of Philosophy*, vol. vii. p. 280.

Sulphuret of Potash.

DXXXIV. When equal parts by weight of potash and powdered sulphur are mixed and exposed in a covered crucible to nearly a red heat, they melt and then combine, forming a mass, which, when poured upon a marble slab concretes into a substance of a dark brown or red colour, hard and brittle. This is sulphuret of potash. From its resemblance to the liver of animals, it was known to the earlier chemists by the name of *Hepar Sulphuris*. Exposed to the air it attracts moisture, acquires a greenish tinge, deliquesces and gives out the odour of sulphuretted hydrogen. The same effect is more speedily produced by moistening it with water, or a diluted acid. It is soluble in water, forming a solution of a yellow colour, but a small portion of the water is at the same time decomposed. Its oxygen is transferred to a portion of the sulphur producing sulphuric acid, which is then neutralized by the potash, while the hydrogen unites with another portion of sulphur forming sulphuretted hydrogen, which remains dissolved in the solution. The liquid may therefore be considered as a solution of sulphuret of potash, sulphuretted hydrogen, and a small quantity of sulphate of potash in water. The decomposition of the water may be owing to the presence of a *sulphuret of potassium*, for according to the experiments of M. M. Gay-Lussac and Vauquelin, this compound exists in sulphuret of potash. The name of sulphuretted hydro-sulphuret of potash has been given to this liquid.

The *hydro-sulphuret* of potash may be formed by transmitting a stream of sulphuretted hydrogen through an aqueous solution of potash. The solution is colourless, but on exposure to the air becomes green and deposits sulphur ; after some time it again becomes colourless, and affords sulphate of potash. The hydro-sulphuret of potash may be obtained in a solid state, crystallized in long 4 sided prisms, with 4 sided pyramids, or in 6 sided prisms terminated by 6 sided

pyramids. It is deliquescent, and forms a solution of the consistence of syrup which gives a green stain to the skin. It is soluble in alcohol and water, and effervesces with acids, but does not deposit sulphur. A third compound of these substances which possesses analogous properties, is that to which Mr. Chenevix gave the name of *Hydroguretted sulphuret*. It may be prepared by boiling potash and flowers of sulphur together in a sufficient quantity of water. The solution is of a deep greenish yellow colour, of a disagreeable alkaline taste, and fœtid odour. It is decomposed by the acids which combine with the potash and precipitate the sulphur perfectly white, or in the state of hydrate. On exposure for some time to the air sulphate of potash is formed, sulphur is precipitated, and the solution becomes limpid. It is employed as a test of the presence of metals, and as an eudrometric liquid.

The uses of potash are numerous and important. It enters into the composition of glass, and of soft soap. It is employed in the art of bleaching, and occasionally for the purpose of softening waters. Combined with the acids it forms saline compounds, some of which are of immense consequence to society. It is a valuable agent to the chemist; for in consequence of the strength of its affinities for the acids, it is able to separate the metals from their acid combinations; and from its power of uniting by fusion with the earths it is frequently employed in the analysis of different earthy compounds.

SECTION II.

Of Sodium.

DXXXV. Soda, also called fossil or mineral alkali, or natron, has been known for many ages. In combination with carbonic acid, it is found in various parts of the earth, and particularly at the natron lakes, as they have been called, in the neighbourhood of Grand Cairo, of which an account

has been given by M. Berthollet. Du Hamel, in the year 1736, first pointed out the difference between soda and potash.

The soda of commerce, in which state it is combined with carbonic acid, is obtained by the combustion of plants which grow on the sea shore ; along the Mediterranean from the *salsola soda* ; and in other parts from the *Algæ*, and different species of *fuci*. The ashes of these plants contain salts, which by the heat employed, are partly fused, and form a dark coloured saline mass, which, in Spain, goes by the name of *barilla*, in France by that of *varec*, and in Scotland and America by that of *kelp*. Carbonate of soda is obtained from this mass by repeated solutions and crystallizations. Carbonic acid may be withdrawn from the soda by the use of quicklime and alcohol, as practised with regard to potash.

Soda prepared in this way is a grayish white opaque mass, which may be obtained, though with difficulty, crystallized in the form of prisms. In taste, in its action on vegetable colours, on oils, and upon animal bodies, it has a perfect resemblance to potash. Its specific gravity however is less. When exposed to heat it melts below ignition, and if in the state of hydrate, has the appearance of effervescence. Exposed to the air it deliquesces, but does not completely liquefy, and after having absorbed carbonic acid it becomes dry.

DXXXVI. Soda, like potash, had been inferred to be compound, but nothing positive was known of its composition until it was decomposed by Sir H. Davy, by the same means which succeeded in demonstrating the nature of potash.* Soon afterwards M. M. Gay-Lussac and Thenard obtained its base in large quantities by exposing it to the action of iron heated to whiteness.† The arrangement was the same as that for potash ; but they found that for its decomposition a higher temperature was required, and that the soda should be passed more slowly over the iron. The easiest mode per-

* Philosophical Transactions for 1808.

† Recherches Physico-Chimiques, t. i. p. 97.

haps of procuring the bases of soda is that of Sir H. Davy, which consists in heating potassium in contact with muriate of soda, common salt, or chloride of sodium. The decomposition takes place readily, without the disengagement of hydrogen gas, and rather more than 1 part of sodium is obtained for every 2 parts of potassium employed.*

Sodium, the name given by Sir H. Davy to the basis of soda, is white, opaque, and has the lustre and general appearance of silver. It is soft and exceedingly malleable, so that when pressed upon by a platina blade, with a small force, it spreads into thin leaves. It appears to possess the property of welding. It is a good conductor of heat and electricity. Its specific gravity, according to M.M. Gay-Lussac and Thenard, is 0.97223.† When exposed to heat it begins to soften at 120° , and is fluid at 180° ; according to the French chemists it requires the temperature of 194° for its fusion. It is not volatile at a degree of heat sufficient to melt plate glass.

On exposure to the air it becomes tarnished, and by degrees covered with a white crust of pure soda, which deliquesces much more slowly than the crust formed in the same circumstances on potassium. At common temperatures it combines slowly with oxygen without the evolution of light; nor does it become luminous until heated nearly to ignition. In oxygen gas it burns when heated with a white light, throws off brilliant sparks, and is converted into soda.

When introduced into chlorine it takes fire spontaneously. It produces no flame when thrown into water, but violently effervesces with a hissing noise, occasions the disengagement of hydrogen gas, and produces a solution of pure soda. Its action with hot water is more violent.

Oxides of Sodium.

DXXXVI. Sodium is capable of combining certainly with 2, and probably with 3 proportions of oxygen.

* Philosophical Transactions for 1811.

† Recherches, t. i. p. 111.

1. When sodium is kept in a phial loosely corked, so that the access of atmospheric air is not altogether prevented, a combination takes place between the metal and oxygen in a manner similar to that of potassium. The substance thus formed is of a grayish white colour, brittle, destitute of metallic lustre, and susceptible of decomposing water, but giving off less hydrogen than an equal weight of sodium. Both Sir H. Davy,* and M. M. Gay-Lussac and Thenard† agree in considering this as probably the protoxide of sodium.

2. If sodium be burnt in a quantity of air containing oxygen, just sufficient to convert it into alkali, a second oxide is formed, which is pure dry soda. Its properties have been already detailed. Soda has a strong affinity for water; for when brought into contact with water, that fluid is absorbed with great violence. Soda obtained in the usual way exists in the state of hydrate, containing about 77 of soda, and 23 of water.

Soda is likewise formed when sodium is made to act upon water.

3. When sodium is consumed in an excess of pure oxygen gas, it is converted into a substance of a dull greenish yellow colour, fusible, and a non-conductor of electricity. Brought into contact with water, oxygen gas is given off, and the liquid becomes a solution of soda. Its excess of oxygen is also abstracted by combustible substances, by the aid of heat, and soda is formed.

The quantity of oxygen in soda has been determined by the amount of hydrogen evolved when sodium was brought into contact with water. M. M. Gay-Lussac and Thenard state the proportions in soda at 74.63 of sodium, and 25.37 of oxygen; or 100 + 33.99. They remark likewise that the quantity of oxygen in the yellow coloured oxide is one and a half times greater than that in soda; if this be the case, it will be composed of 100 metal and 51 of oxygen. But there is rea-

* Elements of Chemical Philosophy, p. 334.

† *Recherches*, t. i. p. 150.

son to believe that there are 3 oxides, and that the first described is a protoxide. If so, their composition will be as follows.

1. *Protoxide.*

		Prop.				
Sodium	-	1	-	100	-	85.48
Oxygen	-	1	-	17	-	14.52
						<hr/> 100.00

2. *Deutoxide or Soda.*

		Prop.				
Sodium	-	1	-	100	-	74.68
Oxygen	-	2	-	34	-	25.37
						<hr/> 100.00

3. *Peroxide.*

		Prop.				
Sodium	-	1	-	100	-	66.22
Oxygen	-	5	-	51	-	33.77
						<hr/> 100.00

The equivalent number for sodium will therefore be 44 ; and the numbers for its oxides as follows ; protoxide 51.5 ; deutoxide 59 ; peroxide 66.5. But soda contains 2 proportions of water ; the hydrate therefore will be represented by $51.5 + 17 = 68.5$.

Chloride of Sodium.

DXXXVII. When sodium is introduced into chlorine gas, it takes fire, burns with brilliancy, and emits bright red sparks ; the gas diminishes in volume, and a solid compound is formed which is chloride of sodium. The same substances may be produced by exposing dry soda, or hydrate of soda, to

the action of chlorine ; the attraction of the metal for this gas is greater than its affinity for oxygen, and the soda is decomposed, in the first case giving off oxygen, in the second, oxygen and water. This chloride has all the properties of *common salt*. It has been known and used from time immemorial. Until within a few years it has been considered by chemists as a compound of muriatic acid and soda, and hence was named *muriate of soda*. If chlorine be a simple substance, this must be regarded as a binary compound of the two elements.

Common salt exists in vast abundance in nature. It is found under the surface of the earth in immense beds ; dissolved in water, it is the principal ingredient in the saline springs which are so common in our own country ; and it constitutes the greatest part of the salts in the waters of the ocean. When this water is evaporated to a certain degree, chloride of sodium is deposited in crystals. But as sea water contains other salts, such as muriate and sulphate of magnesia &c. the salt procured by boiling the water acquires a slightly bitter taste, and the property of deliquescing on exposure to a humid atmosphere. In the large way it may be purified by the ingenious process of Lord Dundonald of Scotland. The salt is put into conical vessels, the apices of which are perforated and placed downward, and over it is poured a boiling hot saturated solution of salt, which, in passing through the mass, will dissolve all the foreign salts, while it can have no effect upon the salt to be purified. In the small way the purification may be effected by dissolving the salt in 4 times its weight of water, filtering if necessary, and dropping into it, first muriate of barytes, then solution of carbonate of soda, so long as a precipitation takes place. The liquid is afterwards to be filtered, and evaporated to a proper degree.

Chloride of sodium, when crystallized, is in the form of cubes, the angles of which are occasionally found truncated ; its taste is purely saline, and it suffers no change on exposure to the air. Its specific gravity is between 1.120 and 1.143.

It is soluble in water, requiring for its solution at 60° , 2.8 parts, and at 212° , 2.76 parts of that liquid. Hence its solubility is very little altered by change of temperature, and to produce crystallization it is necessary that a portion of water should be driven off by evaporation. The specific gravity of a saturated solution at 42° , Dr. Watson found to be 1.198. When exposed to heat it decrepitates from the sudden conversion of its water of crystallization into aqueous vapour, and it loses from 2 to 3 per cent. But pure rock salt, it is said, neither decrepitates nor loses weight by a low red heat. At the temperature of ignition it melts, and in an intense heat, rises in white vapours without suffering decomposition. Common salt is not soluble in pure alcohol, but a small quantity is dissolved by alcohol of the specific gravity of .830.

Common salt has been analyzed by many chemists. Considering it as a chloride of sodium, the proportions of its constituents are

	Berzelius.		Muzel.		Marcet.
Chlorine	59.305	- - -	59.5	- - -	59.5
Sodium	40.695	- - -	40.5	- - -	40.5
	<hr/> 100.000		<hr/> 100.0		<hr/> 100.0*

Its theoretical composition, presuming it to be a compound of 2 proportions of chlorine and 1 of sodium, will be 60.36 of the former, and 39.64 of the latter; and it should be represented by $67 + 44 = 111$.

If, on the contrary, it be regarded according to the old theory, as a muriate of soda, it will consist, according to the most recent analyses, of 46 of muriatic acid and 54 of soda.

This compound is decomposed by some of the acids. With sulphuric acid, the products are muriatic acid gas, and sulphate of soda; with nitric acid, chloride, and nitrate of soda. It is also decomposed by phosphoric and boracic acids, when assisted by heat, and the presence of mois-

* Thomson's Chemistry, vol. ii. 5th ed. p. 331.

ture. Potash also effects a partial decomposition ; and, as has already been stated, potassium deprives sodium of the whole of its chlorine.

Sodium with the assistance of a moderate heat combines with phosphorus ; the compound bears a great resemblance to lead. Thrown into water, it decomposes that liquid, and is converted into phosphate of soda. The same effect takes place when it is heated in contact with the air.

When sodium and sulphur are heated together out of contact with the air, they combine with great energy, evolving both caloric and light. The product is of a dark gray colour, and has properties analogous to sulphuret of potassium.

Salts of Soda.

DXXXVIII. Chlorate of soda. It may be formed by saturating chloric acid with carbonate of soda. It crystallizes in square plates, is very soluble in water, but not deliquescent, and has a taste cooling, and somewhat sharp. On red-hot coals it fuses into globules, giving out a yellow light ; 500 parts of carbonate of soda saturated with the acid, give 1100 of chlorate of soda. When distilled, it yields a great deal of oxygen gas mixed with a little chlorine. The residue, though it had not been heated, is distinctly alkaline.* According to Mr. Chenevix it is composed of 66.2 of acid, 29.6 of soda, 4.2 of water.†

Nitrate of soda, cubic nitre, may be formed by direct combination. Its crystals are of a rhomboidal form, of a cool, sharp taste, somewhat bitter, soluble in water, deliquescent in the air, and decomposable by heat, yielding oxygen. It is composed of about 62.5 of nitric acid, and 37.5 of base.

Sub-borate of soda, borax. This is a salt of some importance, and has been used in the arts for a long period. It is a native production of Thibet, and is dug from the bottom of a lake, in which the production or deposition is constantly going on.

* Vauquelin—Annals of Philosophy, vol. vii. p. 39.—Translated.

† Philosophical Transactions for 1802.

When imported into Europe it is mixed with an unctuous matter and impure. It is said by Pelletier to be deprived of this matter by calcination, and to be purified by subsequent solution in water and crystallization.

Borax is in the form of hexangular prisms, terminated by triangular pyramids, but the crystals are often imperfect, and it is difficult to develop their figures. It is white, and possesses an alkaline and slightly astringent taste. Vegetable blues are converted by it to a green. It is soluble in water, requiring 20 parts of the liquid when cold, and 6 parts when boiling, for its solution. It is slightly efflorescent. Exposed to heat it undergoes aqueous fusion, and after losing its water is converted into a spongy white mass, commonly called *calcined borax*. When heated to ignition it melts into a transparent glass, which remains undecomposed, as it is still soluble in water and crystallizable. It is phosphorescent in the dark by percussion. It is decomposed by sulphuric acid, and on this fact is founded the process for obtaining the boracic acid. Many other acids also separate boracic acid from soda. It is composed, according to Gmelin, of 35.6 of acid, 17.8 of soda, and 46.6 of water.

Borax is used in the arts as a flux to promote the fusion of other substances before the blow-pipe; it is also an ingredient in the glass pastes which are formed in imitation of the gems; and it constitutes an article, though not an important one, of the *materia medica*.

From its taste and its operation on vegetable colours, it is obvious that the properties of the soda are not neutralized, and that it is a sub-borate.

The neutral borate may be formed by saturating the soda in borax with boracic acid, but when thus produced it presents no interesting properties.

Carbonate of soda. Soda is analogous to potash in the property of combining in two proportions with the acids, of which this salt furnishes an example. Two carbonates are known, one in which the acid and alkali are in equal proportions,

the other where there are 2 proportions of carbonic acid to 1 of soda.

1. Carbonate or sub-carbonate. This salt is found native in various parts of the world, particularly in India, Egypt, and in part of Africa, in the form of dense, crystalline masses. In Africa it is called by the natives *trona*. It has also been discovered in solution in the waters of some of the lakes in Hungary and Egypt. For the purposes of commerce it is procured from barilla and kelp, by lixiviations and repeated crystallizations.

It is crystallized in the form of large octoedra, composed of two 4 sided pyramids with rhomboidal bases joined; some in rhomboidal tables; and often in octoedra with the opposite acute angles of the rhomboidal base pretty deeply truncated. Its taste is alkaline, and it changes vegetable blues to a green. Exposed to the air it loses its water of crystallization, and falls into a fine white powder. It is very soluble in water, requiring only 2 parts at 60°, and less than its own weight at 212°. When operated upon by heat, it undergoes aqueous fusion, and is then converted into a dry white mass. At the temperature of ignition it melts into a transparent liquid, and at a higher heat is partly decomposed. It is composed of

		Kirwan.		Bergman.		Berard.
Soda	-	21.58	-	20.00	-	23.33
Acid	-	14.42	-	16.00	-	13.98
Water	-	64.00	-	64.00	-	62.69
		<hr/>		<hr/>		<hr/>
		100.00		100.00		100.00

It is used in large quantities in the arts, in the formation of glass and of hard soap. It is also employed in medicine.

2. Bi-carbonate of soda. This salt may be formed by transmitting carbonic acid through an aqueous solution of the carbonate; by exposing the carbonate to an atmosphere of that acid; or by exposing a saturated solution of the carbonate to heat, mixed with about $\frac{1}{6}$ its weight of sub-carbonate of

ammonia. The liquid deposits an aggregate of crystalline plates.* The taste of this bi-carbonate is milder than that of the preceding, but is still alkaline. Exposed to heat it is deprived of its water and of 1 proportion of carbonic acid, and is converted into sub-carbonate of soda. According to Klaproth it is composed of 39 parts of acid, 38 of soda, and 23 of water; according to Wollaston of 37.1 of soda, 52.2 of acid, and 10.7 of water.

Soda may be super-saturated with carbonic acid, by making a solution of the carbonate in water, and transmitting through it carbonic acid gas. The quantity of the gas combined will be proportional to the lowness of temperature of the solution, and the degree of pressure to which the gas is subjected. A preparation of this kind, familiar by the name of *soda water*, is sometimes employed in medicine, but is more frequently used as an agreeable and wholesome beverage.

Phosphate of soda. This salt has been long known, but it owes its introduction into medicine to Dr. Pearson of London. He prepared it by a direct combination of soda with phosphoric acid; but the usual mode of obtaining it is to add to the acid phosphate of lime, which results from the decomposition of burnt bones by sulphuric acid, as much of a solution of carbonate of soda as will neutralize the properties of the acid. The sub-phosphate of lime is precipitated, and phosphate of soda is procured by filtering and evaporating the liquid.

Phosphate of soda crystallizes in rhomboidal prisms, the taste of which is saline and slightly alkaline without bitterness. It changes delicate blues to a green. At 60° it is soluble in 4 parts, and at 212° , in 2 parts of water. Exposed to the air it effloresces, and, when heated, first loses its water, and is then converted into a white enamel. Before the blow-pipe it melts into a transparent globule, which becomes opaque on cooling. From its easy fusibility it has been employed as a flux by the mineralogists. According to Berzelius it consists of 20.33 of phosphoric acid, 17.67 of soda, and 62 of water.

* Murray's System, 4th ed. vol. ii. p. 618.

It is partially decomposed by the mineral acids and converted into bi-phosphate of soda.

It has been introduced into the practice of medicine as a substitute for other purging salts, its taste being much less offensive, while it is equally active.

Soda combines with phosphorous and hypo-phosphorous acids, forming salts which are of little consequence.

Phosphate of soda and ammonia. This salt, under the names of *microcosmic salt* and *fusible salt of urine*, has been long known; and it was principally from this that the earlier chemists obtained their phosphorus. It is doubtful whether it can be considered as a ternary compound. It seems most probable that it is a union of phosphate of soda, and phosphate of ammonia, for its properties are nearly the same as those of the two salts just mentioned. It crystallizes in small 4-sided prisms which are soluble in water, and efflorescent in the air. It melts very readily before the blow-pipe, and has been preferred as a flux to the phosphate of soda. It is now rarely employed.

Sulphate of soda is one of the most important of the saline compounds of soda. It is familiarly known by the name of *Glauber's salts*, from the chemist who first described its properties. It is the salt with an excess of acid which remains after the distillation of common salt with sulphuric acid, in the process for obtaining muriatic acid. It is also formed in large quantities in the manufactories of sal ammoniac. In this country it is procured from sea water after the extraction of its common salt; the mother water, as it is called, being exposed to spontaneous evaporation. Sulphate of soda is crystallized in long 6-sided prisms, terminated by dihedral summits, the sides of which are grooved. They are transparent, of a saline and bitter taste, and very soluble in water, requiring 2.86 times their weight at 60°, and only $\frac{8}{10}$ at 212°. Exposed even for a short time to a dry air, a white powder forms upon the surface, in the course of a few days the texture of the crystal is destroyed, and the whole is changed to a

smooth, powdery substance. When the efflorescence is terminated, it will be found to have lost 56 per cent. in weight. When submitted to heat it undergoes aqueous fusion, its water is driven off, and at ignition it is melted and partly decomposed.

It is decomposed when heated in contact with carbonaceous matter.

The dry salt consists of 44 of soda and 56 of acid. In its crystallized state it contains 58 parts of water.

Bi-sulphate of soda. Prepared by dissolving sulphate of soda in sulphuric acid, and allowing the solution to remain at rest for some time ; it gradually deposits large rhomboidal crystals, which are acid, soluble in 2 parts of water at 60°, and efflorescent. The excess of acid is driven off by a moderate heat.

Ferro-cyanate of soda. This salt prepared in the same way as triple prussiate, or ferro-cyanate of potash, is of a yellow colour, crystallized in 4-sided prisms with dihedral summits, transparent and of a bitter taste. Exposed to warm air, they effloresce and lose $37\frac{1}{2}$ per cent. of their weight. They are soluble in $4\frac{1}{2}$ parts of cold water, and much less when the water is heated. They are likewise soluble in alcohol. The chemical properties of this salt are similar to those of ferro-cyanite of potash.

SECTION III.

Of Lithium.

DXXXIX. Chemistry is indebted to M. Arfvredson of Sweden, and a pupil of the celebrated Berzelius, for the discovery, within two years, of a substance which possesses the general properties of potash and soda, or in other words exhibits the characters of an alkali. He first obtained it from the mineral called *Petalite*, in the proportion of 3 per cent. Soon afterwards the *Lepidolite* was found to contain about 4 per cent.;

* Annals of Philosophy, vol. xii. p. 15.

and the *Triphane* or *Spodumene*, 8. parts of the new alkali in 100 of the mineral.*

Lithia, which is the name given to this compound, is readily obtained from these minerals by fusing them with potash, dissolving the whole in muriatic acid, evaporating to dryness and digesting in alcohol. The muriate of lithia being soluble is taken up, while the other salts remain, and, by a second evaporation and solution, it will be procured in a pure state.

Another mode practised is to calcine the mineral in fine powder with carbonate of barytes, separating all the earths, and obtaining the alkali in combination with an acid.

Lithia has been submitted to the action of voltaic electricity by Sir H. Davy, and it was decomposed with the same phenomena as the other alkalies. A portion of its carbonate being fused in a capsule of platina, the platina was rendered positive and the saline mass, by means of a wire, negative. The alkali was decomposed with bright scintillations, and the reduced metal being separated, afterwards was burnt. The small particles, which remained a few moments before they were reconverted into alkali, were white, and very similar to sodium. A globule of quicksilver made negative and brought into contact with the alkaline salt, was soon changed to an amalgam, which decomposed water, liberated hydrogen gas, and produced an alkaline solution.† There can be no doubt therefore of the nature of lithia, that it consists of a base analogous to potassium and sodium, and which has been called *Lithium*, combined with oxygen. No other experiments have yet been made upon this base.

With regard to the proportion of oxygen in lithia, it is stated by M. Arfvredson at 43.9 parts, and by M. Vauquelin at 44.84 parts in 100. Hence supposing the oxygen to amount to 45 parts, and the alkali to be a tritoxide, its representative number will be 42.5 ; if a deutoxide, 26.

Chloride of lithium, obtained by evaporating the muriate to dryness and fusing it, is a white semi-transparent body, anal-

* Journal of Science and the Arts, vol. v. p. 337. † Ibid, p. 338.

ogous in composition to the chlorides of the other alkalis, but differing from them essentially in properties. It is extremely deliquescent; it crystallizes with great difficulty from its solution in needle-shaped crystals, and it is very soluble in alcohol, the flame of which is of a fine red, like the salts of strontian. Exposed to heat it melts below ignition, and when heated powerfully in the air, disengages chlorine, absorbs oxygen and becomes strongly alkaline.

Salts of Lithia.

DXL. These have been partially examined by M. Arfvedson, and M. Vauquelin. All of them are soluble, but some are singularly infusible.

Nitrate of lithia. Very soluble—deliquescent—crystallizable in rhomboids—taste, sharp—melts on exposure to heat, with the same phenomena as nitre.

Carbonate of lithia. The sub-carbonate of lithia is but little soluble in water. It may even be precipitated from its sulphate by adding to it a strong solution of carbonate of potash. Cold water dissolves only $\frac{1}{100}$ part, the solution acts powerfully on vegetable colours, and effervesces with acids. It melts with ease, and after fusion, is dissolved with great difficulty even in boiling water. It effloresces in the air, and attracts carbonic acid.

The carbonate, heated on platina, acts upon it almost as powerfully as the fixed alkaline nitrates. It separates ammonia from its combinations, but it is decomposed by lime and barytes, and rendered caustic.

It decomposes solution of sulphate of alumina.

Sulphate of lithia. The sulphate crystallizes readily in small rectangular prisms, which are white and shining, and have a saline taste, differing from the sulphates of potash and soda. This salt is more soluble than sulphate of potash, perhaps less so than sulphate of soda. It is anhydrous, or destitute of water; melts at a heat below redness, and is composed, according to M. Vauquelin, of sulphuric acid 69.18, of lithia 30.82.

The sulphuret of lithia, formed by M. Vauquelin, appears in all respects like the other alkaline sulphurets, excepting in the larger proportion of sulphur thrown down by the acids.

From what we have learnt respecting this new alkali, it appears that it differs from potash and soda,

1. By the fusibility of its salts.
2. By the great deliquescent property of its chloride.
3. By the comparative insolubility of its carbonate.
4. By its great capacity of saturating acids, in which it even surpasses magnesia.*

It was this last property in fact which led to its discovery, for in the analyses of the petalite, the salt formed by its combination with an acid was found to be of a much greater weight than if produced from potash or soda.

SECTION IV.

Of Barium.

DXLI. The mineral called *ponderous spar* is a compound of a peculiar earth, which was discovered by Scheele in 1774, and has since been named *barytes*, with sulphuric acid. It may be obtained free from sulphuric acid by heating it strongly in contact with charcoal powder. The residual mass is then to be lixiviated with water, and the liquid, after being filtered, is to be mixed with solution of carbonate of soda, so long as a precipitate continues to fall. The powder is then to be collected on a filtre, washed with water, and made into balls with charcoal, which are exposed to a high heat in a crucible. When cooled, they are to be washed with boiling water, from which a part of the barytes will be separated in crystals on cooling, and the remainder may be obtained by evaporating to dryness.

Another method has been proposed by Vauquelin, viz. of decomposing the sulphuret of barytes, formed in the first stage of the preceding process, by nitric acid, and driving off the nitric acid from the solid salt by heat.

* Annals of Philosophy, vol. xi. pp. 291. 373. 448.

Barytes may likewise be obtained from the *Witherite* or native carbonate, by exposing it slightly moistened to an intense heat, or more easily by mixing it previously with charcoal, which converts the carbonic acid into carbonic oxide.

DXLII. That barytes consists of a metallic basis combined with oxygen has been sufficiently demonstrated by the experiments of Sir H. Davy, of M. M. Pontin and Berzelius, and of Gay-Lussac and Thenard. By means of voltaic electricity, Messrs. Pontin and Berzelius obtained an amalgam of this basis and mercury; and Sir H. Davy procured it in combination with iron. He found subsequently that by making an amalgam with mercury, and distilling it in a green glass tube filled with the vapour of naphtha, the mercury might be driven off and the metal of barytes, which he named *Barium*, be left in its pure state. Lately Dr. Clarke has decomposed barytes mixed with a little oil, before the flame of the oxy-hydrogen blow-pipe, and he has given to the metal the name of *plutonium*. But this experiment has not succeeded with other chemists.

Barium, procured from the amalgam above mentioned, appeared of a dark gray colour, with a lustre inferior to that of cast iron. It was considerably heavier than sulphuric acid, for though surrounded by globules of gas, it sunk immediately in that fluid. Exposed to the air it instantly became covered with a white crust of barytes, and when gently heated, burned with a deep red light. It decomposed water, producing barytes and hydrogen gas.

Sir H. Davy thinks that barytes is likewise decomposable by potassium.

The attraction between barium and oxygen is prodigiously strong, but the metal has as yet been obtained in so minute a quantity that no direct synthetical experiment has been made to ascertain the proportions in which they combine. But this may be arrived at by calculation. It seems to be a law that, in all cases, acids saturate a quantity of base con-

taining a definite portion of oxygen. Thus 100 of sulphuric acid saturate a base which contains 20 of oxygen ; now this quantity of acid combines with 194 parts of barytes ; and these 194 parts contain 20 of oxygen, which reduced to 100th parts, will give 10.4 of oxygen united with 89.6 of barium in oxide of barium or barytes. In calculating from the composition of the carbonate of barytes, the amount of oxygen will be 10.23 ; the mean of the two is 10.31. Now $10.31 : 89.69 :: 7.5 : 65.3$, the last number then gives the representative of barium, and $65.3 + 7.5$, or 70.8 for barytes, upon the supposition that it consists of 1 proportion each of its elements.

DXLIII. Barytes, as commonly procured, is a solid of a grayish colour, somewhat porous, the specific gravity of which is about 4. Its taste is acrid and even caustic, and when taken internally it operates like an active poison. Exposed to the air it increases in bulk, loses its cohesion, and finally falls into a powder. The same effect is produced more rapidly by the addition of water. It then goes through the operation, which is familiarly called slaking or slacking, and presents phænomena perfectly analogous to those of lime with water. If the affusion of water be continued, the liquid becomes hot and dissolves a considerable quantity of the earth, the greater part of which, as the solution cools, is deposited in the form of transparent prisms, of 6 sides. These crystals on exposure to the air lose about 30 per cent. of water, and become white and opaque. Cold water dissolves about $\frac{1}{20}$ its weight, and boiling water nearly its own weight of barytes. Its solution is generally known by the name of *barytic water*. Its taste is acrid and alkaline, it turns vegetable colours green, and when exposed to the air absorbs carbonic acid and forms an insoluble carbonate. As usually obtained, barytes contains water chemically combined, and it is therefore a hydrate. This hydrate melts at a red heat, but when in a dry state it is fusible only in the intense heat of Dr. Hare's blow-pipe.

Barytes unites by heat with silica and the compound is soluble in acids ; and when barytic water is added to silicat-

cated potash, the two earths are precipitated in combination.

A sulphuret of barytes is readily formed by melting its constituents together. The compound is soluble in water and at the same time decomposes a portion of it, producing sulphuretted hydrogen. An hydro-sulphuret of barytes is separated in the form of hexaedral prisms from the hydro-guretted sulphuret. It is probable that a sulphuret of barium is likewise formed when sulphur and barytes are united in the dry way. Barytes unites with phosphorus and forms a sulphuret of a dark colour, capable of decomposing water, and of producing phosphuretted hydrogen.

Chloride of Barium.

DXLIV. When barytes is heated in contact with chlorine gas, oxygen, according to Sir H. Davy, is given off, and a combination takes place between the chlorine and the barium. It may also be formed by the action of muriatic acid gas on barytes, in which case water is generated by the combination of the hydrogen of the muriatic acid with the oxygen previously united with the barium. According to the experiments of Sir H. Davy, for every 2 volumes of chlorine absorbed, 1 volume of oxygen was given off; so that this chloride will consist of

		Prop.					
Barium,	-	1	-	-	100	-	66.76
Chlorine	-	1		-	51.30	-	33.24
							<hr/>
							100.00

It may be represented by $65.3 + 33.5 = 96.8$.

Chloride of barium or *muriate of barytes*, as it is commonly called, is a salt of some importance to the chemists; hence various processes have been proposed to prepare it with œconomy. The easiest method is to dissolve native carbonate of

barytes in muriatic acid, and crystallizing the solution. It is most commonly obtained from the sulphate.

This salt crystallizes in quadrangular tables, occasionally in double 8-sided pyramids. Its taste is saline, pungent, and disagreeable; it is soluble in about 2.5 parts of water at 190°, and its solubility is but little influenced by difference of temperature. It is soluble in small quantity in alcohol which is not very strong, and communicates to its flame a yellow colour. It suffers no change on exposure to the air. When heated, it decrepitates, and loses its water of crystallization, but suffers no other change.

When concentrated nitric acid is added to its saturated solution, a precipitate takes place of nitrate of barytes, which shows that the nitrate is less soluble than the chloride.

It is decomposed instantly by sulphuric acid, and an insoluble sulphate is formed. From this property, and the strong attraction which subsists between that acid and barytes, the latter is commonly employed as a test of the presence of the former.

This compound has been analyzed by several chemists. Considering it as a muriate it consists of

Barytes	64*	60†	62.47‡	64§	61.85
Acid	20	24	22.93	21	23.35
Water	16	16	14.60	15	14.80
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	100	100	100.00	100	100.00

Viewed as a chloride its elements exist in the proportions above stated, in combination with two proportions of water.

Barium is susceptible of combination with iodine, and of forming an iodide, which crystallizes in fine needles and is gradually decomposed on exposure to the air. It is prepared through the medium of hydriodic acid.†

* Kirwan. † Vauquelin. ‡ Aiken. § Berthier. || Berzelius.

† Gay-Lussac—Memoir on Iodine—Annals of Philosophy.

Salts of Barytes.

DXLV. *Nitrate of barytes* may be prepared by dissolving carbonate of barytes in nitric acid, and evaporating the solution to a sufficient degree. Crystals—regular octoedrons, or small brilliant plates—taste, acrid and austere—soluble in 12 parts of water at 60°, and 3 or 4 parts at 212°.—Decomposed entirely by a strong heat, leaving pure barytes.

The solution of this salt is frequently employed as a test of the presence of sulphuric acid. But both this salt and chloride of barytes are decomposed by the carbonates of potash and soda.

Chlorate of barytes. Crystallizes in rectangular 4-sided prisms, terminated by an oblique face. Its taste is sharp and harsh. It dissolves at 60° in about 4 times its weight of water; but is insoluble in strong spirit of wine. Its aqueous solution when pure is precipitated neither by muriatic acid, nor nitrate of silver. Exposed to heat it yields 39 per cent. of oxygen. The residue is not entirely soluble in water, but a portion remains, which is carbonate of barytes. The solution is alkaline.*

Barytes likewise forms salts with fluoric, fluo-silicic, hydriodic, oxiodic, boracic, phosphoric, phosphorous, and hypophosphorous acids. Of these, the fluat, fluo-silicate, oxiodate, borate, phosphate, and phosphite are insoluble in water, and are obtained by decomposing some of the soluble salts of barytes.

Sulphate of barytes. This compound is found native in considerable abundance, crystallized in bevelled tables, or in flat 6-sided prisms. It may be formed artificially by presenting sulphuric acid to any of the solutions of barytes. It is then in the form of a white and insipid powder, insoluble in water, or at least nearly so, for it requires, according to Kirwan, 43000 times its weight of that liquid for its solution. Its specific gravity is 4.4. It is soluble in hot sulphuric acid,

* Vauquelin—Annals of Philosophy, vii. 39.

and precipitated from it by water. Exposed before the blow-pipe to heat, it decrepitates at least when in mass, and then melts into an opaque globule. If heated in contact with carbonaceous matter, its acid is decomposed, and sulphuret of barytes formed. It is decomposable partially or totally by the alkaline carbonates, and by the chlorides of sodium and calcium.

When powdered, made into cakes with gum tragacanth, and heated, it acquires the property of shining in the dark, after exposure to the rays of the sun, and it forms one of the solar phosphori, by the name of Bolognian phosphorus.

As barytes is used as a test of sulphuric acid, it is of consequence to know precisely the proportions in which they are combined in the sulphate. The analyses of Aiken, Fourcroy, Berzelius, and Davy, give 66 parts of barytes and 34 of acid. This is precisely the relative amount of its constituents as derived from their representative numbers. So that its composition may be stated as follows.

		Prop.						
Barytes	-	1	-	-	194	-	-	66
Acid	-	1	-	-	100	-	-	34
		<hr/>						<hr/>
		2						100

And it may be represented by 72.8 + 57.5, or 110.3.

Ferro-cyanate, or triple prussiate of barytes. This salt was prepared by Dr. Henry, by adding powder of prussian blue to a boiling solution of barytes in water, until it ceased to be discoloured. On filtrating and sufficiently evaporating the solution, crystals are obtained which have the form of rhomboidal prisms, a yellow colour, and a peculiar taste. They are soluble in 1920 parts of cold water, and 100 of boiling water; likewise soluble in nitric and muriatic acids, but are decomposed by sulphuric acid. It is composed, according to Mr. Porrett of acid 34.31, barytes 49.10, water 16.59.

All the salts of barytes are poisonous, and from their activity upon animals Dr. Crawford was induced to employ them as medicines. He used principally the muriate in solution, and recommended it as an efficient remedy in scrophula, but after much experience of its powers, it is found not to deserve the reputation which it once acquired.

SECTION V.

Of Strontium.

DXLVI. The compounds of strontium are so analogous to those of barium, that the difference between them was not pointed out until the year 1791 or 1792, when the subject was investigated by Dr. Hope, and shortly after by M. Klaproth and Mr. Pelletier.*

Strontian, strontia, or strontites, for this compound of strontium has been recognized by all these names, constitutes the basis of two minerals, a sulphate and carbonate, in which respect it resembles barytes. It may be obtained from them by the same modes which have been found successful in separating barytes from its combinations.

It commonly appears in the form of a porous mass of a grayish white colour, of an acrid, alkaline taste. It acts upon vegetable blues, changing them green. Its specific gravity is 1.6; but it is not like barytes poisonous. When thrown into boiling water it dissolves, and as the solution cools it is deposited in the form of thin quadrangular tables, which on exposure to the air effervesce and become white and opaque. These crystals are soluble in 50 parts of water at 60°, and in half their weight at 212°. It is likewise soluble in small proportion in alcohol. Exposed to heat the crystals of strontian undergo aqueous fusion, and then become dry, in which state it requires the intense heat of the oxy-hydrogen blow-pipe to be rendered

* Transactions of the Royal Society of Edinburgh, vol. iv.—Klaproth's Analytical Essays.—Nicholson's Journal, vol. i. p. 518. 4to series.

liquid. By heat the crystallized strontian loses 68 per cent. in weight.

Sir H. Davy decomposed strontian in the same way as barytes, by electrifying it in contact with mercury, and distilling off the latter in a tube free from atmospheric air. To the base he gave the name of *strontium*. It was analogous in properties to barium. Its lustre was not considerable, it was difficultly fusible, and not volatile. On exposure to the air it attracted oxygen, and was converted into strontian; and when thrown into water, decomposed it with violence, hydrogen gas was evolved, and the water became a solution of strontian. Like barium it sunk in sulphuric acid. As yet strontium has been procured in quantities too small to permit any very accurate or extensive examination of its properties.

From the quantity of sulphuric and carbonic acid saturated by strontian it has been inferred that 100 parts contain about 15.25 parts of oxygen; so that if strontian be considered as consisting of 1 proportion of each element, the number for strontium will be 41.6, and that for its oxide 49.1.

DXLVII. *Chloride of strontium.* When strontian is heated with chlorine, oxygen gas is given off and a chloride of strontium is formed, from which it appears that this metal has a stronger attraction for chlorine than for oxygen. The compound may likewise be formed by the action of muriatic acid gas on strontian; or by adding carbonate of strontian to liquid muriatic acid till all effervescence ceases and evaporating to a sufficient degree; on cooling the chloride, or the *muriate*, as it was called, will be deposited in the form of long, slender, hexagonal prisms, of a sharp, penetrating taste, deliquescent in a humid atmosphere, and very soluble in water, requiring only twice its weight at 60°. It is likewise soluble in about 24 parts of alcohol, and it imparts to the flame of that liquid a fine purple colour. Strong muriatic acid, added to a saturated solution of this salt in water, causes a precipitate of minute crystals of chloride, and nitric acid, of crystallized nitrate. Exposed to heat it melts and loses 42

per cent. of weight, from the evaporation of its water. It consists of

		Prop.				
Strontium	-	1	-	146.29	-	59.39
Chlorine	-	1	-	100.00	-	40.61
		<hr/>				<hr/>
		2				100.00

Iodide of strontium may be formed in the same way as iodide of barium.

DXLVIII. *Chlorate of strontian* may be formed by saturating chloric acid with strontian. It has a sharp, somewhat astringent taste—very soluble in water—deliquescent—crystallized with difficulty—melts on red-hot coals—and gives out a fine purple flame. *Fluate, hydriodate, and oxiodate* of strontian may be formed in the same way as the analogous salts of barytes.

Nitrate of strontian. This salt may be formed by dissolving native carbonate of strontian in hot nitrous acid, or in nitric acid diluted with at least its own weight of water. When the solution is evaporated, it produces crystals which are either hexaedra pyramids, or octoedrons, with the apices of the pyramids or angles truncated. Its taste is saline and pungent; it is very soluble in water, deliquescent in a humid atmosphere, but efflorescent in dry air. It deflagrates slightly on burning coals. Exposed to heat this salt decrepitates, melts, and is then decomposed, the nitric acid is driven off, and strontian remains. It is not soluble in alcohol, but when mixed with it, if a paper be moistened with the liquid and be burnt, it consumes with a purplish red flame. It contains no water of crystallization, and its proximate elements, viz. the acid and base are nearly in equal proportions by weight.

Carbonate of strontian. The native carbonate is a rare and beautiful mineral, crystallized in prisms, or of a radiated or columnar structure. The artificial carbonate may be formed by decomposing a salt of strontian by an alkaline carbonate,

and it is then in the form of a white, insipid, and insoluble or rather difficultly soluble powder. It is partially decomposed by heat alone, and totally when previously mixed with charcoal powder. Thrown in powder on live coals it produces red sparks. It consists of about 70 of strontian and 30 of carbonic acid.

Sulphate of strontian. When found native it is crystallized in rhomboidal prisms of a shade of blue. Prepared artificially by decomposing a salt of strontian by sulphuric acid, it is a white powder, insipid, and difficultly soluble in water. According to different analyses it contains from 42 to 46 parts of acid, and from 54 to 58 of base.

The characters by which the salts of strontian are distinguished from those of barytes are

1. They give to the flame of alcohol a purplish red colour, while it is yellow from those of barytes.
2. Succinate of ammonia produces no precipitation in a solution of a salt of strontian, as it does from a barytic salt.
3. Salts of strontian are not precipitated by ferro-cyanite of potash.
4. The salts of strontian are decomposed by barytic water.
5. The watery solution of strontian is not, like that of barytes, precipitated by gallic or malic acid.
6. The salts of barytes are poisonous; those of strontian are inert.

The sulphuret, hydro-sulphuret, and hydroguretted sulphuret of strontian are similar in properties to the analogous compounds of barytes; so likewise is the phosphuret.

Strontian is at present applied to little or no use.

SECTION VI.

Of Calcium.

DXLIX. Calcium is the radical of lime, which in a state of combination has been known from the earliest ages. It exists

in vast abundance in nature, as it constitutes the basis of all the marbles, limestones, as well as of the bones and shells of animals. It is also found dissolved in the waters of the ocean and in many mineral waters.

Lime may be obtained pure by exposing the crystallized calcareous spars to an intense heat; or by dissolving oyster shells in muriatic acid, filtering the solution and adding a little ammonia to it to ascertain whether it contain magnesia, or alumina, and then precipitating the lime by solution of pure carbonate of potash. The white powder is then to be collected and washed with large quantities of water, dried and ignited to whiteness.

From the experiments of Sir H. Davy there is no doubt that lime is a compound of oxygen with a base which is metallic, though he did not perfectly succeed in his attempts to procure it pure. To this base he gave the name of *calcium*. It appeared whiter and possessed of greater metallic brilliancy than barium and strontium, and burned when gently heated into quicklime. When the amalgam of calcium is brought into contact with water, hydrogen gas is given off, and the water becomes a solution of lime. Potassium, transmitted in vapour over the surface of lime ignited to whiteness, is converted into potash; and a dark gray substance of metallic splendour, which is calcium either wholly, or in part deprived of its oxygen, is found imbedded in the potash; the mass effervesces violently with water, and disengages hydrogen gas. From calculation, the composition of the salts of lime being taken as the data, 100 parts of calcium are inferred to combine with about 39 parts of oxygen; or lime will be composed in round numbers of 72 of calcium and 28 of oxygen. Hence if it be considered as a compound of 1 proportion of each, the representative number for calcium will be 19.28; and that of oxide of calcium or lime $19.28 + 7.5$, or 26.78.

DL. Lime is white and moderately hard; it has an alkaline, acrid taste; it operates, when long applied to animal bodies, like a caustic, and gives to vegetable blues a tinge of

green which, after a while, changes to a yellow. Its specific gravity is 2.3. When pure it is fusible only in the intense temperature of the oxy-hydrogen blow-pipe; it then appears in the form of a vitreous globule. Exposed in a mass for some time to the air, it gradually increases in bulk, its cohesion lessens, and it finally falls down in the form of a white and apparently dry powder. The same phenomena are immediately produced by bringing it into contact with water. The mass swells up, becomes very hot, and in the dark phosphorescent, much aqueous vapour is produced, and if the water have not been in excess a powder is formed which is hydrate of lime, and which contains, chemically combined, 25 per cent. of water. This process is familiarly known by the name of slaking. The water may be driven off by a strong red heat.

If the affusion of water be continued, a portion of the lime amounting to $\frac{1}{756}$ part of the liquid is dissolved. Mr. Dalton affirms that lime is less soluble in hot than in cold water. This solution is commonly known by the name of lime-water. Its taste is austere and disagreeable, and it operates upon vegetable colours like lime itself. Lime cannot be crystallized in common circumstances from this solution; but M. Gay-Lussac succeeded in obtaining it in 6-sided prisms, by inclosing lime-water in an exhausted vessel with sulphuric acid, on the principle of Mr. Leslie's ingenious experiments. Lime-water on exposure to the air attracts carbonic acid, a crust of carbonate of lime forms upon its surface, which after a while subsides, and is replaced by another, until the whole is separated from the liquid. The same absorption takes place when solid lime is exposed to the atmosphere.

Phosphuret of Lime.

DLI. Lime combines with phosphorus, and the compound was first formed by Dr. Pearson of London. Into a glass tube about 8 or 10 inches in length and $\frac{3}{4}$ of an inch in diam-

eter, hermetically closed at one end, is introduced from 1 to 2 drachms of dry phosphorus in small pieces; over this are placed fragments of pure quicklime to within an inch of the mouth of the tube; the remaining space is filled with powder of lime, and the orifice is closed with clay. The tube is coated with sand and clay, and when this is dry, it is laid across a small furnace in such a way as that the heat shall be applied only to the part containing the lime. In a short time the phosphorus melts and boils, and its vapour, coming into contact with the lime, combines with it and forms a substance of a chesnut brown colour, and of a disagreeable odour. When thrown into water, it decomposes the liquid, phosphuretted hydrogen is formed, which rises to the surface and is immediately inflamed. The effect is more positive when warm water is employed. There remains behind phosphate and hypo-phosphate of lime, the latter being in solution.

Sulphuret of Lime.

DLII. Equal parts of lime and sulphur, both in powder, when heated together in a covered crucible, combine, and form a sulphuret of a reddish brown colour, which decomposes water and forms a yellow coloured hydro-sulphuret of lime, or hydroguretted sulphuret. The same compound may be formed by boiling together equal parts of these substances in 10 times their weight of water for an hour. A reddish yellow liquid is formed, which from its strong attraction for oxygen is employed in its recent state as an eudiometric substance. It was thus employed by Dr. Hope in the ingenious eudiometer which he invented.* Exposed to the air for some time it is decomposed and sulphate of lime formed. It is also rapidly decomposed by the acids, sulphur being precipitated.

Chloride of Calcium.

DLIII. When lime is brought into contact with chlorine gas and heated, oxygen gas is disengaged from the former,

* Plate i. fig. 3.

and the calcium unites with the latter, forming a chloride of calcium. The same compound may be formed by adding lime to liquid muriatic acid, the hydrogen of the acid combining with the oxygen of the lime, forming water, and the two other elements uniting with each other. It is also the result of the operation of obtaining ammonia by quicklime and muriate of ammonia. When its solution is evaporated, it may be obtained in the form of the 6-sided prism, terminated by 6-sided unequal pyramids. Its taste is saline, sharp, and bitter; it is extremely deliquescent, and very soluble in water, requiring for its solution at 60° only $\frac{1}{3}$ of its weight; at 212° it is soluble in almost any quantity. A saturated solution, made at 60° , will deposit a considerable quantity of crystals when its temperature is reduced to 32° . The crystallization is often beautiful. This compound is likewise soluble in alcohol. Exposed to heat it undergoes aqueous fusion, then becomes dry, and is partially decomposed. It is decomposed by some of the acids, by the alkalies, and by the alkaline salts, at least by the sulphates, carbonates, and phosphates. It is composed of

	Prop.					
Calcium	-	1	-	-	57.55	- 36.53
Chlorine	-	- 1	-	-	100.00	- 63.47
		<hr/>				<hr/>
		2				100.00

Its representative number therefore is $33.5 + 19.28$, or 53.7 .

Chloride of calcium, or *muriate of lime*, is employed by the chemist, in consequence of its strong attraction for water, to dry elastic fluids in delicate experiments. It has likewise been made an article of the *Materia Medica*.

Iodate of lime. This salt may be formed by the direct combination of its proximate elements. It is usually in powder, but may be obtained in small quadrangular prisms. It is soluble in water, decomposable by heat, and consists of 100 of iodic acid, and 17.57 of iodine.

Fluate of lime. It exists native and constitutes a beautiful mineral. It is commonly crystallized in cubes, the angles of which are sometimes truncated. The primitive form of the fluat is the octoedron. It is characterised by its variety of colours, in which the purple is predominant. It is insipid, inodorous, insoluble in water, and unaffected by the air. Fluat of lime phosphoresces when its powder is thrown on a heated iron. Some varieties of it phosphoresce, according to Grotthus, by the heat of the hand. The artificial fluat likewise possesses this property. Exposed to a very high temperature it melts into a transparent glass. It is decomposed by sulphuric acid, and if free from silica, produces pure fluoric acid; if it contain that substance, fluo-silicic acid results.

Some doubts exist respecting the real nature of this compound. It has generally been regarded as composed of fluoric acid and lime; while the experiments and observations of Sir H. Davy lead strongly to the belief that it is a fluoride of calcium.

If it be considered as a fluat, it will consist, according to the analyses of Klaproth and of Dr. Thomson, of 32.5 of fluoric acid, and 67.5 of lime.

But if it be a fluoride, then it will be composed of fluorine 43.37, calcium 56.63.

Fluat of lime is employed in the arts, in the formation of various ornaments, and of fluoric acid.

Oxy-muriate of lime. It would seem that chlorine was capable of entering into combination with oxide of calcium, or lime, and of forming a peculiar compound.

This compound, which is extensively used in the art of bleaching, may be prepared either in the humid, or the dry way; in the first by transmitting a stream of chlorine through slaked lime diffused in water which is kept in constant agitation; in the second by bringing the gas into contact with dry slaked lime. The resulting salt is in the form of a soft white powder, sometimes granular, which gives out the odour of chlorine, and is partially soluble in water, producing a bleach-

ing liquid. According to Mr. Dalton there is always a portion of muriate of lime formed during this process. When this powder is thrown into water, one half of the lime is deposited, the other is dissolved and constitutes an oxy-muriate; hence he infers that the powder is a sub-oxy-muriate. When a solution of oxy-muriate of lime is evaporated, part of the acid (*or chlorine*) escapes, the rest is converted into muriatic acid, and muriate of lime alone remains; so that a dry oxy-muriate cannot be obtained in solution. Mr. Dalton determined the amount of oxy-muriatic acid in this compound by the quantity required to convert a given amount of green sulphate of iron into the red sulphate; a test which he regards as equally delicate and convenient. According to his experiments, the dry powder consists of 13.5 of muriate of lime, 44.5 of sub-oxy-muriate of lime, and 42 of water. But age diminishes the proportion of the oxy-muriate of lime, even in its dry state; for a quantity of it 5 years old yielded 30 of muriate of lime, 12 of sub-oxy-muriate, 26 of free lime, with traces of carbonic acid, and 32 of water.

The pure dry salt he infers is composed of 23.2 of oxy-muriatic acid, 38.4 of lime, and 38.4 of water; when dissolved in water it consists of 54.7 of acid and 45.3 of lime; and after a current of the gas has been transmitted through it, of 70.7 of acid, and 29.3 of lime.*

Chlorate of lime. Taste, sharp and bitter—deliquescent—very soluble in water and alcohol—when heated undergoes aqueous fusion.—According to Chenevix consists of 55.2 of acid, 28.3 of lime, 16.5 of water.

Nitrate of lime. It may be prepared by dissolving pure marble in diluted nitric acid, filtering the solution, and evaporating to a sufficient degree. When slowly produced the nitrate is in the form of 6-sided prisms, but is usually procured in long and slender needles, of an acrid, bitter taste, and as soluble in water and alcohol as the chloride or muriate. It is extremely deliquescent. When heated to dryness it consti-

* Annals of Philosophy, vol. i. p. 15.—vol. ii. p. 6.

tates Baldwin's phosphorus. In a higher heat it is decomposed. Its composition has been variously stated. Considering the dry salt as containing 1 proportion each of nitric acid and lime, it will consist of nitric acid 65.39, and of lime 34.61.

Nitrate of lime is applied to the same uses as the muriate.

Carbonate of lime. The great masses of limestone rock found on the globe, consist of lime combined with carbonic acid. It is likewise often seen crystallized in an immense variety of figures, of which the primitive form is a rhomboidal prism, the angles of which are in the ratio to each other of $101\frac{1}{2}^{\circ}$ to $78\frac{1}{2}^{\circ}$.

The carbonate may be formed by pouring solution of an alkaline carbonate into a solution of a salt of lime. It is produced also by passing a current of carbonic acid gas, and even by blowing air from the lungs, through lime-water. It is an insipid, inodorous, and insoluble powder, which suffers no change on exposure to the air, and which, when strongly heated, gives off carbonic acid, and is converted into quick-lime. When heated under great pressure, it retains its carbonic acid, and forms a mass resembling spar, or marble.* Bucholz effected the same change by heating highly in a crucible $4\frac{1}{2}$ pounds of chalk.†

Carbonate of lime is decomposed by all the acids with a brisk effervescence.

According to the analysis of Dr. Wollaston, it is composed of 56.30 of lime, and 43.70 of carbonic acid. Its theoretical composition, derived from the representative numbers of its proximate elements, almost exactly agrees with this analysis. By these it is composed of

		Prop.					
Lime	-	1	-	-	128.98	-	56.32
Acid	-	1	-	-	100	-	43.68
		<hr/>					<hr/>
		2					100.00

* Sir James Hall—Ed. Philosophical Transactions, vol. vi.

† Nicholson's Journal, vol. xvii. p. 230.

Hence it will be represented by $26.7 + 20.7$, or 47.4 .

The tendency to union between carbonic acid and lime is great; hence lime-water is one of the best tests of the acid. If however there be an excess of acid, as for example, when lime-water is added in small proportion to an aqueous solution of carbonic acid, the carbonate, immediately after its formation, dissolves in the liquid. It is doubtful whether it is to be considered as a solution of carbonate of lime, or whether a bi-carbonate be not formed which is soluble in water, and decomposable at a moderate increase of temperature.

Phosphate of lime. There exist several varieties of this salt, and much difficulty has been experienced in determining the number of definite proportions in which phosphoric acid and lime unite. Dr. Thomson, who has made these compounds a subject of research, inferred that they were capable of combining in no less than 6 proportions.* But he has since limited them to 4.†

These are described under the names of *phosphate*, *bi-phosphate*, *quadriphosphate*, and *sub-phosphate*. Of these, the phosphate is the most important. It is the basis of the bones of animals, but mixed with carbonate of lime, and animal matter. To be obtained pure, calcine bones to dryness, dissolve the white substance in muriatic acid, and add pure ammonia so long as a precipitate continues to fall; collect the solid upon a filtre, wash it with water, and then dry it.

It is in the form of a white powder, inodorous, insipid, insoluble, or nearly so in water, and permanent in the air. It is melted in a white heat, but not decomposed. It is soluble in acetic, nitric, muriatic, and sulphuric acids, when diluted, and precipitated from them by ammonia, and by the alkaline carbonates; but if the latter be in excess it will be redissolved. It is decomposed by strong sulphuric acid.

This salt is composed, according to Dr. Thomson, of 100 of phosphoric acid, and 97.775 of lime.

* Annals of Philosophy, vol. vii. p. 306.

† System of Chemistry, vol. ii. p. 459. 5th ed.

The *bi-phosphate* is formed by dissolving phosphate of lime in pure diluted phosphoric acid. The solution has an acid, and disagreeable harsh taste. Evaporated it forms a dry, white mass, deliquescent, and soluble in water, but not in acids. Composed of 100 of acid and 40.27 of lime.

Quadriphosphate of lime is formed by digesting phosphate of lime in as much sulphuric acid as is sufficient to combine with the whole of the lime. One quarter part of the phosphate remains in solution in the acid combined with a portion of the phosphoric acid which had been separated from the lime by the sulphuric acid. It is capable of being crystallized in silky fibres, or thin plates, is soluble in water, and of an acid taste. Exposed to heat it melts into a transparent glass, which has long been known by the name of *glacial phosphoric acid*. By heat it is decomposed by bi-carbonate of potash.

Sub-phosphate of lime exists native, and is known by the names of apatite and spargel or asparagus stone.

Sulphate of lime. This compound, known under its common name of gypsum, or plaster of Paris, is found in great abundance in nature, both amorphous and crystallized in lenticular crystals, or in octoedrons, or 6-sided prisms. Artificially prepared, by decomposing a salt of lime by sulphuric acid, it is in the form of a white powder, insipid to the taste, soluble in about 400 times its weight of water at 60°, and permanent in the air. Heated violently it melts into an opaque, vitreous globule. It is decomposed by the pure alkalis, by alkaline carbonates, and by barytes.

The dry salt is composed of 41.67 of lime, and 58.33 of sulphuric acid.

In its common state, sulphate of lime contains about 21 per cent. of water. On exposure even to a moderate heat, this water is driven off, and a dry white powder remains, which is capable of exerting a strong affinity for, and of combining again with that liquid. Hence, if no more water be added than has been previously evolved, a combination immediately commences, the mass grows warm, and of greater consist-

ence, and a solid is finally the result. From this property, gypsum, it is well known, is employed in the formation of stucco, for busts, &c.

It is likewise extensively used as a manure in agriculture.

Anhydrous sulphate of lime. This sulphate is destitute of water, whence is derived its name. It is found native in masses of a foliated structure, of a pearly lustre, harder, and of a higher specific gravity than the common sulphate. It is comparatively rare.

Ferro-cyanate, or triple prussiate of lime. It is formed by boiling 56 parts of lime water, on 2 parts of prussian blue, which has been well washed with hot water. The process should be stopped when the liquid produces no change in the colour of turmeric. After filtration, the solution has a greenish-yellow colour, and an unpleasant bitterish taste; evaporated to dryness it yields small crystalline grains, soluble in water, but insoluble in alcohol.

The principal use of lime in the arts is in the composition of mortar for building. It is likewise employed in agriculture, and in medicine.

SECTION VII.

Of Magnesium.

DLIV. When solution of carbonate of potash is added to a solution of Epsom salts in about twenty times their weight of water, a spongy precipitate of a white colour is formed, which, when collected upon a filtre, washed with large quantities of water, and dried by exposure to a red heat for some time, constitutes magnesia.

This substance was decomposed by Sir H. Davy, by the same means which he found to succeed in the case of barytes, strontian, and lime. More decisive effects however were produced by the use of potassium. When the vapour of this metal was passed through magnesia heated to intense whiteness out of contact with the air, and a little mercury was sub-

requently introduced into the tube, an amalgam was obtained, which, by distillation, afforded a dark gray, metallic film, infusible at the temperature of melting plate glass, and which, in the process of distilling the mercury, rendered the glass black at its point of contact with it. This film burned, when heated strongly, with a red light, and became converted into a white powder, which had the character of magnesia; when a portion of the metal was thrown into water, it sunk to the bottom, and effervesced slowly, becoming covered with a white powder; by adding a little muriatic acid to the water, the effervescence was violent, the metal rapidly disappeared, and the solution was found to contain magnesia.

There can be but little doubt therefore that the composition of magnesia is analogous to that of lime, and the other alkaline earths; but the decomposition is more difficult, and the results are not so positive.

From the quantity of magnesia necessary to neutralize 100 parts of sulphuric acid, which has been found equal to 50.06 parts, it may be inferred that it is an oxide composed of 60 of magnesium, and 40 of oxygen; and if it be considered as containing 1 proportion each of these elements, it will consist of

	Prop.						
Magnesium	-	1	-	-	100	-	60
Oxygen	-	1	-		50	-	40
		<hr/>					<hr/>
		2					100

The equivalent number for magnesium will thus be 11.25. But from the large quantity of oxygen contained in magnesia, and from its high saturating property, may it not be considered as a deutoxide? If so, the equivalent number will be 30, and that of magnesia, $30 + 15 = 45$.

DLV. Oxide of magnesium or magnesia is in the form of a white powder, soft, inodorous, but possessing a slight and peculiar taste. It converts vegetable blues to a green. Its specific gravity is about 2.3. It is one of the most infusible

substances in nature, being melted with some difficulty even in the intense heat of the oxy-hydrogen blow-pipe.

Magnesia combines with water, and forms a hydrate. In this state it is precipitated from its acid combinations in a gelatinous form. But a solid compound of this kind is found crystallized in folia, of a pearly lustre, at Hoboken in New-Jersey, and consists, according to Dr. Bruce, of 70 of magnesia, and 30 of water.

Magnesia, when dry, absorbs nearly its own weight of water, but does not, like alumina, form with it a plastic, ductile mass. It is very sparingly soluble in water, requiring for its solution, according to Kirwan, 7000, and according to Dalton, 16,000 times its weight of that liquid.

Magnesia unites with sulphur, though not very readily, and forms compounds analogous to those of the other alkaline earths, but which have not been very accurately examined.

Salts of Magnesia.

DLVI. Magnesia combines with the acids and forms salts, which, for the most part, are soluble in water, possess a bitterish taste, are decomposable by ammonia, the alkalies, and their carbonates, and by phosphate of soda, on the addition of ammonia, a triple compound being formed. Magnesia is likewise characterized by its disposition to produce triple compounds.

Chloride of magnesium, or muriate of magnesia. When magnesia is heated in chlorine, oxygen gas is given out, and the chlorine takes its place, forming a chloride, which has been known for some time by the name of *muriate of magnesia*. It may likewise be formed by the action of muriatic acid gas on magnesia, or by dissolving its carbonate in liquid muriatic acid. It is found in considerable proportion in seawater, and may be obtained by the evaporation of the bittern or mother water.

This salt is exceedingly soluble, and therefore crystallizes with difficulty in small needles. Its taste is bitter and acrid; it is very soluble both in water and pure alcohol, and in its solid state, deliquesces rapidly on exposure to the air. When strongly heated, muriatic acid is formed and passes off, and magnesia remains. It consists of 1 proportion of chlorine 33.5, and 1 of magnesium 11.25.

This salt is frequently mixed with common salt, and it gives to the latter a bitter taste, and the property of becoming moist on exposure to a humid atmosphere.

When a stream of chlorine is passed through water holding magnesia in suspension, a liquid is prepared, which possesses some advantages over the oxy-muriate of lime in some cases of bleaching.* It has been applied to this purpose by Mr. Rainsay.†

Magnesia combines with chloric, iodic, hydriodic, fluoric, and boracic acids, and forms salts, which, however, are applied to no use.

DLVII. The principal salts of magnesia, are the carbonate, sulphate, and ammoniaco-magnesian phosphate.

Carbonate of magnesia. This compound may be formed by adding together solutions of carbonate of potash, and sulphate of magnesia, the carbonate of magnesia being precipitated. For commercial purposes it is prepared by heating sea-water after the separation of common salt, and adding to it a solution of pearlsh, or of impure carbonate of ammonia. The whole is poured on canvass, frequently washed with water, and the residue is divided into cubes by means of a frame of wood. These cubes are subsequently dried in stoves or heated rooms. Much care is requisite in order to obtain the carbonate of a good quality.

When well prepared it is perfectly white, nearly insipid, of little coherence, and of a specific gravity equal to about 2.3. It is very sparingly soluble in water. Exposed to heat it loses

* Sir H. Davy.—Elements of Chem. Philos. p. 243.

† Tilloch's Philosophical Magazine, vol. xl. p. 326.

its carbonic acid, and is converted into what is commonly called *calcined magnesia*. A small mass of carbonate opposed to the flame of the oxy-hydrogen blow-pipe, becomes surrounded by an insupportably brilliant light.

According to the experiments of Kirwan, 100 parts of the carbonate consist of 43 of magnesia, 40 of carbonic acid, and 17 of water. Considering it as a compound of 1 proportion of each, its theoretical composition will be of

Magnesia	-	-	-	47.47
Acid	-	-	-	52.53
				<hr/>
				100.00

It may be represented by $18.7 + 20.7$, or 39.4 .

Bi-carbonate of magnesia. Fourcroy ascertained that when carbonate of magnesia was diffused in water, and a stream of carbonic acid transmitted through it, a portion was dissolved, and that on spontaneous evaporation the solid salt might be obtained. It crystallizes in hexagonal prisms, terminated by hexagonal planes. Its taste is slight; it is soluble in 48 parts of water at 60° , and it effervesces on exposure to the air. When heated, it decrepitates, loses its water of crystallization, and falls down in a powder.

It is composed of

	Prop.					
Magnesia	-	1	-	-	100	-
Carbonic acid		2		-	221	-
		<hr/>				
		2				
						<hr/>
						100.00

Its water of crystallization amounts to 25 per cent. The dry salt may be represented by $41.4 + 18.7$, or 60.1 .

The use of carbonate of magnesia is almost exclusively confined to the practice of medicine. In consequence of the injurious effects which result from taking into the system large quantities of this solid, its liquid preparation has been

lately employed, and it is formed precisely like soda water. The bi-carbonate is dissolved in the water.

Sulphate of magnesia. This compound which is familiarly known by the name of *epsom salt*, from the circumstance of its having been first procured from the mineral waters of Epsom in England, is prepared by boiling down the bittern of sea-water after the common salt has been separated. It is usually crystallized in small needles or fine prisms, but by slow evaporation of its solution, it may be procured in long quadrangular prisms, terminated by 4-sided pyramids. Its taste is saline and bitter: it is soluble in rather more than its own weight of water at 60° , and in $\frac{3}{4}$ of its weight at 212° . It effloresces on exposure to the air. Exposed to heat it loses its water of crystallization, but is not decomposed, in an intense temperature it melts into an opaque, vitreous globule. Various analyses of this salt have been made, the mean of which will give 32.46 parts of sulphuric acid, 18.12 of magnesia, and 49.42 of water. In calculating from the representative numbers, its composition may be thus stated,

	Prop.						
Sulphuric acid	1	-	-	67.08	-	-	32.86
Magnesia	1		-	32.92		-	16.14
Water	-	6	-	-	-	-	51
	<hr/>						<hr/>
	8						100.00

It may be represented by $37.5 + 18.4 = 56.2$, or by $56.2 + 51 = 107.2$.

Sulphate of magnesia is employed almost exclusively in the practice of medicine.

Phosphate of magnesia may be prepared by dissolving magnesia in phosphoric acid, or more economically by mixing solutions of phosphate of soda and sulphate of magnesia; in a few hours the salt will be deposited in 6-sided prisms, of a slightly sweetish taste, efflorescent, soluble in 15 parts of cold water, falling into powder on exposure to heat, and then melting into a transparent glass.

Phosphate of magnesia and ammonia. This triple salt exists in the urine of animals, and composes in part or altogether the substance of some urinary calculi. It was discovered and its properties were investigated by Fourcroy and Vauquelin. It is deposited from urine, on long standing, in the form of small 4-sided prisms, insipid, soluble in water, and unalterable in the air. It is decomposed by heat, ammonia is given off, and the phosphate of magnesia melts into glass. Distilled with charcoal it yields phosphorus. It consists, according to the French chemists, of 33.3 of magnesia, 33.3 of acid, and 33.3 of water.

Magnesia likewise forms triple salts with sulphate of potash, and sulphate of soda.

DIVISION III.

Metals which absorb oxygen at high temperatures, and which when heated to redness decompose water.

This division includes Iron, Tin, Zinc, and Manganese.

SECTION I.

Of Iron.

DLVIII. Iron, as it is the most common, so it is likewise the most valuable of the metals. It is diffused throughout the earth with a lavish hand ; it is found in every class of bodies, and verifies the fine expression of Haüy,—that when Nature takes the pencil, iron is the colour she always uses. This metal has been known from time immemorial. It is familiarly mentioned in the pentateuch, and occasionally in the poems of Homer. The progress of the arts and sciences may be said to be owing in a great measure to the application of iron and its compounds to the various objects of human industry. In the time of the alchemists, it was designated by the name of *Mars*, and until lately many of its medicinal preparations were familiar to physicians by titles derived from this term.

DLIX. Pure iron is of a bluish white colour, of considerable brilliancy, particularly when polished, of a slight taste, and of a peculiar odour when rubbed between the fingers. In hardness it is superior to many of the metals ; it is malleable, ductile, and tenacious. It cannot be beaten into thin leaves, but it may be drawn into very fine wire, and its tenacity is such that a wire of this metal only $\frac{7}{10000}$ of an inch in diameter will support a weight of 549 pounds. Its mean specific gravity is 7.70. Iron is characterized by two very important properties.—It is attracted by the magnet, and is itself capable of acquiring the magnetic property, by being suspended in a vertical position, by the action of electricity, and by the operation of the violet ray of light. When pure, however,

iron retains its magnetic power only for a short time, but if it contain a small proportion of inflammable matter, such for example as carbon, this property is much more durable. By this power it is distinguished from all other metals excepting nickel and perhaps cobalt. The other valuable property which is almost peculiar to iron is that of being *welded*. When two pieces of malleable iron at a full red heat are brought into contact, and beaten, they gradually become incorporated, and form one uniform mass. It is this property of welding alone which permits the artist to work the pure metal, and to fashion it into instruments of various kinds. There is no other metal except platina which exhibits this property, and that to a degree much less than iron.

Iron requires an intense temperature for its fusion. Mr. Wedgewood estimates it at 154° of his pyrometer, and Sir George Mc Kenzie at 158° , a degree of heat which, if protracted upon the scale of Fah., would amount to more than 22000° .

The texture of iron is distinctly fibrous, and by the process of Mr. Daniell these fibres may in a great measure be developed.

Oxides of Iron.

DLX. Iron is capable of combining with two different proportions of oxygen, and of forming two oxides, one of which is black, and the other red.

1. *Black or protoxide.* When a filament of cotton, previously dipped in melted sulphur, is inflamed at the end of a coil of iron wire, and plunged into oxygen gas, the metal burns vividly, throwing out brilliant sparks, and small globules which are usually hollow, are deposited at the bottom of the receiver; these are of a brilliant black colour, and brittle. This is the black oxide. It may likewise be formed, 1. By heating iron red hot and plunging it into cold water; scales will appear on the surface which may be detached by a hammer. 2. By passing the vapour of water over ignited iron.

3. By moistening iron filings with water and allowing the mass to be at rest for a time. 4. By the attrition of flint and steel. 5. By pouring solution of potash into solution of green vitriol, and exposing the precipitate to a moderate heat out of contact with the air.

The oxide obtained by these processes is black, insoluble in water, but soluble in the acids, forming solutions which have a green colour and an astringent taste. It is capable of combining with water and of forming a hydrate, which has a dull greenish colour, and is easily decomposed by heat. It is obtained by precipitating the oxide from its acid combinations by an alkali.

2. *Red or peroxide.* When iron is long exposed to the air its surface becomes covered with a yellowish red substance, which is the peroxide in union with carbonic acid. It may be obtained pure by keeping iron filings at a red heat for some time while exposed to the air, or by heating in the same way the black oxide. A solution of green vitriol in water, after long exposure to the air, will yield this oxide by the action of an alkali; and the same effect may be produced in a solution of green vitriol, saturated with nitrous gas, which has been allowed to stand for some months. The pigments called *ochres* are coloured by this oxide.

This oxide is red, insipid, insoluble in water, but soluble in acids, though with much less facility than the black oxide, and it forms solutions which are of a brownish or yellowish red colour, and of an astringent, metallic taste.

Though the quantity of oxygen in these two oxides seems to have been ascertained with sufficient precision, yet great difficulty has been experienced in reconciling them with the theory of definite proportions. The mean of the analyses of the most distinguished chemists assigns as the composition of the black oxide 100 of metal + 28.78 of oxygen, or 77.66 of the former to 22.34 of the latter. The constituents of the red oxide have been stated at 100 of metal + 43.5 of oxygen. Rejecting the decimal parts which prevent these from bearing

a simple ratio to each other, the red oxide may be said to contain $1\frac{1}{2}$ times as much oxygen as the black oxide. Accordingly it is necessary upon the principles of the atomic theory to conceive the red oxide to be formed of 2 atoms of iron, united to three of oxygen, or to infer that the black oxide is a deutoxide, and the red a tritoxide; the protoxide of iron probably existing, though it has not yet been discovered. Both of these modes are obviously hypothetical; besides which, as observed by Dr. Murray, from the equivalent number of the black oxide, as inferred from its saline compounds, it must be inferred to be a protoxide.* Dr. Thomson supposes the black oxide to be a compound of 1 atom of iron and 1 of oxygen, and the red oxide to consist of 2 of iron, united with 3 of oxygen.† It would perhaps be the wisest course at present to avoid giving an equivalent number for iron, and to wait for the results of future researches. If, however, the existence of a protoxide should be taken for granted, it must be conceived to contain about 11.17 parts of oxygen, and this would give 52 as the representative number of iron.

Chlorides of Iron.

DLXI. Iron is capable of combining with two proportions of chlorine, and of forming two compounds, which may be designated by the names of chloride and perchloride of iron.

1. *Chloride.* This compound may be formed by dissolving iron in muriatic acid, evaporating to dryness, and heating the residue to redness in close vessels. The muriate consists of muriatic acid and oxide of iron; by heat it is inferred to be decomposed, the oxygen of the oxide and the hydrogen of the acid combining to form water, while the two radicals unite and form the chloride. According to Dr. J. Davy the texture of this compound is lamellated, it is gray, and exhibits various shades; its lustre is metallic. Exposed

* System of Chemistry, vol. iii. p. 327. 4th ed.

† Ibid, vol. i. p. 371. 5th ed.

to a red heat, it becomes liquid, but is not volatilized; and when thrown into water, partly dissolves, forming a solution of green muriate of iron.* It consists, according to Dr. Davy, of 53.2 of chlorine, and 46.8 of iron.

2. *Perchloride of iron.* When iron wire is heated red hot and plunged into chlorine, the ignition continues, and the vessel becomes filled with yellowish red fumes, which soon condense into a substance of a bright brown colour, of a high metallic lustre, capable of being volatilized by a moderate heat, and of crystallizing in iridescent plates. When thrown into water it acts violently upon it, and forms solution of red muriate of iron. This compound was first examined by Sir H. Davy. It is composed of 3 proportions of chlorine and 1 proportion of iron.

Iron forms with iodine an *iodide* of a brown colour, fusible at a red heat, and soluble in water, part of which it probably decomposes, and produces hydriodate of iron.†

A compound of iron with silicon and carbon was obtained by Stromeyer and Berzelius, by heating together silex, iron, and charcoal; the globule obtained was white, had a metallic brilliancy, and with muriatic acid gave out more hydrogen gas, than would have been produced by an equal weight of pure iron.

Iron with Carbon.

DLXII. Of all the compounds of iron with other bodies those with carbon are the most important, for they constitute the varieties of *steel*.

The fact that carbon is contained in and is essential to this substance was first ascertained by Bergman. In analyzing different varieties of steel, by dissolving them in the acids, he always obtained a quantity of carbon.‡ The subsequent experiments of Vauquelin confirmed this discovery, and established the proportions in the pieces subjected to

* Philosophical Transactions for 1812, p. 181.

† Gay-Lussac—Memoir on Iodine. ‡ Opusc. t. iii. p. 1.

trial;* and the processes for forming these compounds, together with the philosophy of the actions which produced them, were stated in a very able memoir of M. M. Vandermonde, Monge, and Berthollet.† Morveau likewise contributed to develop the nature of steel by his famous experiment of heating diamond in contact with malleable iron, for the former disappeared while the latter increased in weight, and was converted into steel; an experiment which has since been successfully repeated by Mr. Children.

The quantity of carbon varies in different species of steel. In all, the proportion by weight is small, amounting to from $\frac{1}{180}$ to $\frac{1}{140}$ part. Besides carbon, Bergman affirmed that he obtained manganese, but Vauquelin found none of that metal in the specimens which he examined. The following tables of M. Vauquelin show the substances contained in 4 pieces of steel, and their relative proportions.

	1.	2.	3.	4.
Carbon -	0.00789	0.00683	0.00789	0.00631
Silica - -	0.00315	0.00273	0.00315	0.00252
Phosphorus	0.00345	0.00827	0.00791	0.01520
Iron	0.98551	0.98217	0.98105	0.97597
	<hr/>	<hr/>	<hr/>	<hr/>
	1.00000	1.00000	1.00000	1.00000

It is probable that the radical of the silica, or silicon, was combined with the iron, and that it became oxygenized in the processes of separating it.

Mr. Mushet has likewise stated the proportions of carbon in the different species of steel and of cast iron.‡

* Nicholson's Journal, vol. i. p. 210. 4to.

† Ibid, vol. ii. p. 64. 4to.

‡ Philosophical Magazine, vol. xiii. p. 142.

Soft cast steel	-	contains	-	-	-	-	$\frac{1}{120}$
Common cast steel	-	-	-	-	-	-	$\frac{1}{100}$
Harder cast steel	-	-	-	-	-	-	$\frac{1}{90}$
Steel too hard for drawing	-	-	-	-	-	-	$\frac{1}{80}$
White cast iron	-	-	-	-	-	-	$\frac{1}{25}$
Mottled cast iron	-	-	-	-	-	-	$\frac{1}{20}$
Black cast iron	-	-	-	-	-	-	$\frac{1}{15}$

DLXIII. All the steels have been reduced to three species, viz. natural steel, steel of cementation, and cast steel.

1. *Natural steel.* When iron is first procured from its ores, it is in the form of cast or pig iron. White cast iron contains $\frac{1}{25}$ of carbon. It is crystallized in small facets, and is extremely hard and brittle. Mottled cast iron is of a granulated texture, softer, less brittle, and more easily worked than white iron. Black cast iron is the least valuable of these three species of cast iron. It is more unequal in its texture, more brittle, and melts at a lower temperature. Cast iron is converted into natural steel by exposing it to an intense heat while its surface is protected from the air. By these means one portion of the carbon combines with the oxygen contained in cast iron, and passes off in gas, while the remainder enters into combination with the iron. This is the least valuable of the three species of steel.

2. *Steel of cementation* is formed by stratifying bars of malleable iron and charcoal powder in a trough of peculiar construction, which is closed, and exposing it to an intense heat for several days. The bars, when converted into steel, exhibit elevations or protuberances upon their surfaces, which are technically called blisters, and this species is known in commerce by the name of *blistered steel*. When broken to pieces, welded, and drawn into bars, it is known by the name of *shear* or *German steel*. Its quality is much superior to that of natural steel. It is harder, more elastic, of a finer and more equal texture, and requires to be forged with more precaution. It is employed in the fabrication of agricultural instruments, springs, files, and many articles of cutlery.

3. *Cast steel.* This species is prepared by melting steel of cementation in a crucible or small furnace with a certain proportion of charcoal powder, and pounded glass. By this process, say the French chemists, the flaws and veins are made to disappear, and a mass of a close and equal texture is obtained. Cast steel is very valuable. Its close grain, its extreme hardness, its elasticity, and the high polish of which it is susceptible, adapt it to the fabrication of the sharpest and most delicate of instruments. Hence of this species are formed surgeons' instruments, razors, watchmakers' tools, and various articles of cut steel.

After the formation of instruments of steel, such as knives, swords, &c. they require to be hardened, and the process is effected by heating them to a cherry red visible by day light and plunging them into cold water. They are sometimes heated to this degree in melted lead. This process renders the instrument exceedingly hard, and brittle, so that it is necessary to make it less so, by *letting down*, or *tempering* the steel, which is done by heating the article until its surface exhibits a peculiar colour. The shades of colour are dependent upon the temperature, and by duly regulating the heat, they may be obtained at will. The article is commonly heated in oil. According to Mr. Stodart's experiments, a temperature of 430° Fah. produces upon steel a faint yellowish tint, and renders it proper for razors and scalpels; at 450° the colour is a pale straw, and the steel is adapted to the fabrication of penknives, razors, and other fine edged tools. As the heat is increased, the colour deepens, and at 500° exhibits a bright brownish metallic yellow, slightly inclining to purple. An uniform deep blue is formed at 580° ; and the intermediate shades between 500° and 580° are yellow, brown, red, and purple, which are exhibited irregularly on different parts of the surface.* The colour which indicates the greatest hardness is the light straw yellow.

* Nicholson's Journal, vol. iv. 4to. p. 127.

It has been sufficiently demonstrated that the colours are owing to the oxidizement of the iron, the colour being deeper in proportion as the film of oxide becomes thicker, or as the iron is converted into peroxide.

Figures of various kinds are formed on the blades of swords, and on other articles, by means of an oily composition; the instrument is then tempered by being heated sufficiently, and the colour appears upon the surface which had not been covered.*

Steel may be distinguished from iron by the black stain left upon its surface when a drop of nitric acid is placed upon it.

The mineral substance, called plumbago or graphite by mineralogists, which is commonly known by the name of black lead, is a carburet of iron, containing from 4 to 10 per cent. of iron.

Phosphuret of Iron.

DLXIV. Iron may be combined with phosphorus, forming a compound which is white, has a metallic appearance, is brittle, attractable by the magnet, fusible, and decomposable in a strong heat, the phosphorus being disengaged. A phosphuret of this kind exists in one species of iron, and renders it very brittle when cold, so that it falls to pieces under the hammer. It is called cold short iron.

The phosphuret may be formed, by adding phosphorus by small portions at a time to red hot iron filings; or by melting together 16 parts of glacial phosphoric acid, 16 of iron, and $\frac{1}{2}$ part of charcoal powder.

Sulphurets of Iron.

DLXV. Iron and sulphur have a strong mutual affinity; in certain circumstances they combine, and form a chemical

* Thomson's System, vol. i. p. 372.

compound. It appears that the metal is capable of uniting in two definite proportions with sulphur, producing a sulphuret, and a bi-sulphuret. Both may be formed artificially, and both are found native.

1. *Sulphuret of iron.* When a mixture of 2 parts iron filings with 1 flowers of sulphur, is heated in a covered crucible, combination takes place, and at the same moment the mass glows with a full red heat. The mass when cold has somewhat of a variegated appearance, it is brittle, and easily reduced to a black powder. Exposed to a strong heat it melts, and when cold has a yellowish colour, a metallic lustre, and a crystalline texture. Moistened with water, or a diluted acid, it gives out the odour of sulphuretted hydrogen, particularly in the latter case. It is the compound usually employed in the production of that elastic fluid. This compound exists in nature, and constitutes the mineral known by the name of *magnetic pyrites*.

2. *Bi-sulphuret of iron.* By melting the artificial sulphuret with a quantity of sulphur, the iron unites with another proportion of that substance, and is converted into the bi-sulphuret. It is found native, crystallized in cubes of different sizes, possessing a bright yellow colour, and metallic lustre. Its specific gravity is about 4.5. It is very hard, for it strikes fire with steel; and it is acted upon with great difficulty by the acids. Before the blow-pipe it gives out the odour of sulphur, and leaves a black globule, attractable by the magnet.

The sulphuret is composed of

Iron	-	68	-	-	100
Sulphur	-	37	-	-	58.75
		<hr/>			
		100			

The bi-sulphuret of

Iron	-	53.92	-	-	100
Sulphur	-	46.08	-	-	127
		<hr/>			
		100.00			

Iron, when heated almost to whiteness, decomposes cyanogen in part ; it becomes brittle, and covered with a thin coating of charcoal.*

Salts of Iron.

DLXVI. Most of these salts are soluble in water. When the protoxide constitutes the basis, triple prussiate of potash affords with them a white precipitate ; and tincture or infusion of galls, a very light shade of purple. The precipitate from the pure alkalies is white, with a light shade of green or yellow. The solutions of these salts have a green colour.

The colour of the solutions of salts which contain the red or peroxide is reddish yellow. Prussiate of potash throws down from them a pigment of a beautiful deep blue ; and tincture of galls produces a deep purple verging on black. The alkalies separate a substance of a reddish yellow colour. The green coloured solutions, on long standing and exposure to the air, become reddish and deposit a quantity of peroxide.

Phosphate of soda produces a white precipitate ; the alkaline hydro-sulphurets a black precipitate ; and succinate of ammonia from the red solutions one which is nearly flesh red.

DLXVII. *Chlorate of iron.* Chloric acid dissolves iron without the evolution of gas, but considerable heat is produced. The colour of the solution is first green, but soon changes to a red. The tests above mentioned operate upon it according as it is green or red. It is not susceptible of crystallization, but by heat forms a gelatinous mass.

Muriate of iron. Muriatic acid dissolves iron with facility ; the iron becomes oxidized at the expense of the water, and hydrogen gas is disengaged. It unites with both oxides and forms with one a muriate, with the other a per-muriate.

1. *Muriate.* When filings of iron are put into liquid muriatic acid, effervescence takes place, the iron dissolves, and a green coloured solution forms, which, on evaporation, yields

* Gay-Lussac.

crystals of a pale green, of a very styptic, metallic taste, very soluble in water, and in alcohol, and decomposable by heat, producing chloride of iron. By employing the artificial sulphuret of iron, the hydrogen preserves the iron in the state of black oxide ; the solution should be boiled at the end of the process to free it from sulphuretted hydrogen. Exposed to the air it attracts oxygen ; it likewise decomposes nitric acid ; it absorbs nitrous gas with avidity, and the solution may be employed as an eudiometric liquid.

2. *Permuriate*. This compound may be formed by dissolving red oxide of iron in muriatic acid. It is scarcely crystallizable. Its taste is astringent ; its colour yellow ; it is extremely soluble in water, and deliquescent. It is decomposed by heat and yields per-chloride of iron. Exposed to heat in close vessels with muriate of ammonia, a yellow sublimate is formed which was formerly called *martial flowers* ; it is the muriate of ammonia and iron of the pharmacopæias. This muriate is soluble in alcohol, and is employed in medicine by the name of tincture of muriate of iron. The aqueous solution of this salt is decomposed by sulphuric acid, ferro-cyanic acid, and by the alkalies, and alkaline earths.

Nitrate of iron. Nitric acid, slightly diluted, acts with great violence on iron, and large bulks of nitric oxide are produced, a portion of water is likewise decomposed, hydrogen is disengaged, which unites with azote from the acid, producing ammonia ; this ammonia combines with nitric acid, nitrate of ammonia is formed in the liquid, and if the latter be saturated with quick-lime, the odour of ammonia becomes perceptible. Two nitrates may be formed.

1. *Nitrate*. Obtained by dissolving iron slowly in diluted nitric acid and exposing the liquid to the air. The solution is greenish ; it affords precipitates of hydrated black oxide ; and on exposure to heat is converted into per-nitrate.

2. *Pernitrate*. Formed by pouring nitric acid, diluted with an equal weight of water, by little at a time, on iron filings. A solution of a brownish red colour forms, which

should be digested for some time on filings of iron. It still has an acid taste, is incapable of crystallizing; and of course is exceedingly soluble in water. By evaporation it is partly decomposed, red oxide of iron being precipitated. When diluted with water, and heated with excess of carbonate of potash, a part, if not the whole, of the precipitate is redissolved, producing a brownish solution, which was formerly used in medicine by the name of Stahl's alkaline tincture of steel. The per-nitrate of iron is decomposed by heat.

Carbonate of iron. The rust which forms on iron after long exposure to the air is peroxide of iron in combination with carbonic acid. It may likewise be produced by decomposing sulphate of iron by an alkaline carbonate; a precipitate of dark and dull green forms, which, on exposure to the air, becomes black. When iron is kept for some time in water saturated with, or containing carbonic acid, it becomes oxidized and a portion is dissolved, forming a solution of an astringent and metallic taste, which affords iron by the usual tests. For medicinal purposes the solution is made in Nooth's apparatus.

One species of mineral water is produced by this solution of iron in carbonic acid. On exposure to the air the acid escapes, and the red oxide is precipitated. Hence the margin of springs of this kind is often coated with red ochre.

According to Bucholz, carbonate of iron is found in nature, crystallized in rhombs, which are greenish yellow, transparent, brittle, and of the specific gravity of 3.3.*

Phosphate of iron. Phosphoric acid combines with both oxides of iron, and produces two compounds, the phosphate, and per-phosphate, or what has been called by some, oxy-phosphate.

Phosphate of iron may be formed by mingling solutions of sulphate of iron, and phosphate of potash or soda, filtering the liquid, and washing the residue with water. It has a blue colour, is insoluble in water, and permanent in the air.

* Thomson's Chemistry, vol. ii. p. 527. 5th ed.

Exposed to a violent heat it melts into a globule which exhibits a metallic lustre. If heated with charcoal it is decomposed, and phosphuret of iron formed. It is found native, both amorphous, and crystallized. The substance called *native prussian blue*, which is found in meadows mixed with bog ore, is phosphate of iron; it is remarkable that when first taken up, it is nearly colourless, but on exposure to the air changes to a blue. This ore is massive or in the form of powder, of a blue colour; it is impure and is mixed with variable proportions of alumina and silica. It ought not therefore to be employed in medicine.

This phosphate, when crystallized, is in the form of small prisms, of an indigo blue. It is composed of 21 of phosphoric acid, 45 of black oxide of iron, and 34 of water.

2. *Perphosphate*. Prepared by mixing solutions of permuriate of iron, and phosphate of potash, or soda. It is a white powder, nearly insoluble in water, but soluble in acids, and precipitable by ammonia. In a strong heat it fuses into an ash-coloured globule. It is decomposed, and converted into phosphuret of iron by being heated strongly with charcoal. When treated with the pure fixed alkalies, a brownish red powder is separated, which consists of perphosphate with an excess of base.

Sulphate of iron. This is the most important of all the salts of iron. It may be prepared by pouring diluted sulphuric acid upon iron filings, an effervescence takes place, hydrogen gas is disengaged, and a green coloured solution is formed. For the purposes of commerce, it is obtained in the large way by the decomposition of iron pyrites, by roasting the ore, moistening it with water, and allowing it to be exposed for some time to the air. The sulphur and iron both become oxygenated, the one forms an acid, the other an oxide, which then combine and constitute a sulphate. This salt is washed from the bed of ore, the solution is boiled down to a sufficient degree in leaden vessels, and then drawn off into the crystallizing vat, where it concretes.

Concentrated sulphuric acid does not act upon iron unless heated, it is then decomposed, and converted into sulphurous acid gas. Sulphuric acid combines with both oxides of iron, forming characteristic compounds.

1. *Sulphate of iron.* In this salt the iron exists in the state of black oxide. In commerce it is known by the names of *copperas* and *green vitriol*. In chemical works it is often called green sulphate of iron. When the recent solution of iron in diluted sulphuric acid is evaporated, it produces crystals of a rhomboidal form, and of a fine green colour, translucent, possessing an astringent, metallic taste, and capable of reddening vegetable blues. This salt is soluble in $\frac{3}{4}$ of its weight of boiling water, and in twice its weight of cold water.* It is efflorescent, and when exposed to heat undergoes aqueous fusion; if the heat be high, it is subsequently decomposed, its sulphuric acid is driven off, and a red powder remains which the earlier chemists called *colcothar of vitriol*. It was from this salt that sulphuric acid was obtained, before the present method was practised. Hence its old name of oil of vitriol. This salt in solution is decomposed by the alkalies, and alkaline earths, and their combinations. The mean of the different analyses of this salt by distinguished chemists, gives 27.40 parts of sulphuric acid, 27.30 of black oxide of iron, and 45.30 of water.

When the recent solution of this salt is exposed even for a short time to the air, it attracts oxygen, and a portion of per-sulphate is formed. This disposition to become more highly oxidized is so great, that the solution of the perfectly green sulphate can be procured only with much difficulty. The best mode is to cause diluted sulphuric acid to act upon the artificial sulphuret of iron; the sulphuretted hydrogen formed prevents the iron from becoming highly oxidized, and after the process is finished, the solution should be heated to drive off the superfluous gas. The pure green sulphate gives a white precipitate with triple prussiate of potash.

* Thenard.

2. *Per-sulphate, or red sulphate of iron.* The solution of green sulphate on long exposure to the air absorbs oxygen, its colour changes to a yellowish red, and a portion of peroxide of iron is deposited; for in proportion as this oxide is formed, it requires more acid for its combination, or neutralization. The same salt may be obtained by adding nitric acid to the solution of the green sulphate, and cautiously heating the liquid to disengage the nitric oxide gas, and the excess, if there be any, of the nitric acid. This red sulphate is incapable of crystallization. It is decomposed by the alkalies and alkaline earths, peroxide of iron being precipitated. It forms with triple prussiates, precipitates of a dark blue, and with tincture of galls a black or concentrated purple liquid. It is composed, according to Berzelius, of 60.44 of acid, and 39.56 of red oxide of iron.

The green vitriol of commerce, in consequence of exposure to the air, must be considered as a mixture of these two sulphates.

The sulphate of iron is extensively employed in the arts of dyeing and ink-making.

Ferro-cyanate, or prussiate of iron, prussian blue. This rich pigment is not a pure ferro-cyanate of iron. It is prepared by calcining ox-blood with potash, dissolving the soluble parts of the residue in water, and adding this solution to solution of a definite quantity of alum and green vitriol. A dark greenish precipitate is formed, which assumes a beautiful blue when washed with muriatic acid. The use of muriatic acid is to dissolve and remove the superfluous oxide of iron. Prussian blue therefore is a mixture of ferro-cyanite of iron and alumina, which answers the purpose of diluting the colour. This powder is insoluble in water and in acids, and is not affected by the air. It is decomposed by heat, the elements of the acid are separated, and oxide of iron remains behind. The iron in prussian blue is in the state of peroxide. It is likewise decomposed by the alkalies. When boiled with potash it loses its colour, oxide of iron is disengaged, and the potash is changed to ferro-cyanate or triple prussiate.

It consists, according to Mr. Porrett, of

Ferruretted chyazic acid	-	53.38
Peroxide of iron	- - -	34.23
Water	- - -	12.39
		<hr/>
		100.00

The uses of prussian blue as a pigment are doubtless familiar.

Iron combines with potassium and sodium, but these alloys have not been particularly examined. When aided by an intense heat, iron decomposes potash and soda ; but these metals in their turn are able to decompose the oxides of iron.

SECTION II.

Of Zinc.

DLXV. Zinc is obtained from its native oxide and sulphuret, which are named by mineralogists *calamine*, and *blende* ; the metal itself is commonly called *spelter*. In this state it is not perfectly pure, as it contains lead and sulphur. From these it may be purified by solution in diluted sulphuric acid, precipitating the foreign metals by a plate of zinc, decomposing the solution by carbonate of potash, and igniting the precipitate with charcoal powder.

The colour of zinc is white, with a shade of blue ; it has a high metallic lustre ; its structure is lamellated, and it emits a peculiar odour when rubbed between the fingers. Its specific gravity is from 6.86 to 7.1, the lightest being considered as the purest.

It is rather soft ; when beaten with a hammer, it flattens and then cracks ; but if previously heated to near its melted point and then struck, it falls into grains. It may be granulated by melting it in an iron mortar and stirring it continually with the pestle until nearly cold. When equable pressure is applied to zinc, it may be reduced to pretty thin leaves.

which are elastic but not very flexible. If it be exposed to a temperature somewhat above 212° , its malleability becomes so much increased that it may be hammered into thin plates, and when annealed, be rendered quite flexible. It may even be drawn into wire, and turned upon the lathe. Zinc is susceptible of crystallization, and Pelletier succeeded in obtaining it in flattened prisms. Exposed to heat in close vessels, it sublimes unaltered. Its melting point is about 680° .

Oxide of Zinc.

DLXVI. Zinc has a strong attraction for oxygen; when exposed in its melted state to the air, its surface soon becomes covered with a gray pellicle, which, when removed, is succeeded by another, until the whole is converted into oxide. Oxide of zinc may likewise be formed by transmitting the vapour of water over the ignited surface of this metal. If exposed to a strong red heat in contact with the air, zinc takes fire, burns with an intensely bluish white light, and white flakes, resembling wool, rise in abundance from the vessel. Hence the name of *lana philosophica*, applied to this substance by the earlier chemists. This oxide is white, and incapable of volatilization. Exposed to heat it melts into a glass. It is the only oxide known, and according to the analyses of Gay-Lussac and Berzelius contains 19.61 per cent. of oxygen; so that it is composed of

			Prop.					
Zinc	-	-	1	-	-	100	-	80.39
Oxygen	-	-	1	-		24.4	-	19.61
			<hr/>					<hr/>
			2					100.00

This will give 30.7 as the representative number for zinc, and $30.7 + 7.5$, or 38.2, for the oxide.

This oxide may be used as a paint, and it was formerly employed in medicine.

Chloride of Zinc.

DLXVII. When zinc filings are projected into chlorine, they take fire, burn with brilliancy, and form a compound of a grayish white colour, and semi-transparent. The same compound may be formed by distilling a mixture of granulated zinc, and corrosive sublimate; or by dissolving the metal in muriatic acid, evaporating to dryness, and exposing the mass to a red heat in a tube with a narrow orifice. Formed in this way it is volatile, sublimes when heated, and crystallizes in needles. Its taste is very acrid, and it acts upon the skin like a caustic. It was this compound which was known by the name of *butter of zinc*. It acts upon water and dissolves in it, producing much heat, and the alkalies throw down from its solution, oxide of zinc. It is composed, according to Dr. J. Davy, of equal weights of chlorine and zinc. Its theoretical composition will be

		Prop.				
Chlorine	-	1	-	100	-	52.28
Zinc	-	1	-	91.31	-	47.72
		<hr/>				<hr/>
		2				100.00

and it may be represented by $33.5 + 30.7 = 64.2$.

Iodide of Zinc.

DLXVIII. By the assistance of heat, zinc may be made to combine with iodine. The compound is destitute of colour, fusible, volatile, and capable of crystallizing in small quadrangular crystals. It is deliquescent, and very soluble in water, which becomes acid, and from which the iodide cannot be obtained in a crystallized form by evaporation. Oxide of zinc is precipitated from it by the alkalies, and hydriodic acid and iodine are disengaged by sulphuric acid. Hence the iodide decomposes water, and forms hydriodate of zinc. The

iodide consists of 100 of iodine, and 26.225 of zinc; the hydriodate of 100 of acid, with 32.352 of oxide of zinc.

Sulphur and phosphorus combine with the oxide of zinc and form peculiar compounds.

Sulphuret and Phosphuret of Zinc.

DLXIX. Zinc can be made to combine with sulphur only with great difficulty. It was found by Mr. E. Davy that when the vapour of sulphur was passed over heated zinc, a compound was formed of a white crystalline appearance, and of a yellowish colour, analogous to the native phosphorescent *blende*. When solution of sulphuretted hydrogen, or of hydrogenretted sulphuret is poured into a solution of sulphate of zinc, a white precipitate, which has been considered as a sulphuret, forms, and on drying becomes brown. The native sulphuret of zinc, called *blende*, has been carefully analysed by Dr. Thomson, who found it composed of zinc 100, sulphur 48.84. Its composition derived from calculation, supposing it to consist of 1 proportion of each of these elements, would be 100 + 50.

Phosphuret of zinc is formed when phosphorus is brought into contact with melted zinc. The compound has the colour of lead, exhibits a metallic brilliancy, and when filed or hammered, gives out the odour of phosphorus.

Salts of Zinc.

DLXX. *Chlorate of zinc.* Chloric acid dissolves zinc without effervescence, the solution is astringent, the salt is very soluble, and crystallizes with difficulty in short octaedrons. Heated in a phial it gives out oxygen and chlorine, and a white mass remains, which is a mixture of chloride, and sub-chloride of zinc. The salt detonates on burning charcoal. Vauquelin does not consider it as a pure salt.*

* Annals of Philosophy, ix. 42.

Nitrate of zinc. Nitric acid is decomposed with violence by zinc. When the acid is diluted, zinc dissolves in it, and the solution by evaporation yields crystals in the form of hexaedral prisms, deliquescent, soluble in water and alcohol, decomposable by a gentle heat, and fulminating on burning charcoal.

Carbonic acid in water dissolves zinc slowly, and oxide of zinc with greater facility. It does not crystallize.

Sulphate of zinc. This salt for the purposes of commerce is prepared like the analogous sulphate of iron. It may be obtained in a purer state by dissolving zinc in diluted sulphuric acid, the metal becoming oxidized at the expense of the water. During this solution a black substance separates, which is a mixture of some of the metals with charcoal.

Sulphate of zinc crystallizes in slender 4-sided prisms, which have an astringent taste, are soluble in about 3 times their weight of water at 60°, and when exposed to heat, dissolve in their own water of crystallization. It is decomposed in a strong heat, its acid being expelled.

The commercial salt, which goes by the name of *white vitriol*, is in masses, hard, of a granulated texture, with a tint of yellow. Its solution in water yields, during evaporation, a precipitate of peroxide of iron. According to Berzelius it is composed of 32.585 of acid, 30.965 of oxide of zinc, and 36.45 of water.

Sulphite of zinc. Sulphurous acid in solution dissolves oxide of zinc without effervescence. The solution on evaporation yields crystals which are astringent, less soluble in water, and more easily crystallized than sulphate of zinc. Exposed to the air they absorb oxygen, and are changed to sulphate. They are insoluble in alcohol.

Sulphurous acid acts upon zinc, a portion both of the acid and the water is decomposed, and sulphuretted hydrogen is disengaged. When the solution is evaporated to the consistence of a syrup, it deposits slender quadrangular prisms, terminated by 4 planes, which are soluble in water, and in

alcohol, and on exposure to the air, become white and form an insoluble powder. Before the blow-pipe it swells up, emits a brilliant light, and forms dendritical ramifications. This salt Dr. Thomson considers as a *hypo-sulphite* of zinc;* it differs in properties from the sulphite, and it is very probable that the acid contained in it consists of sulphur united with 1 proportion of oxygen.

Zinc combines with potassium and forms an alloy of the colour of pounded zinc, brittle, granular, and caustic. It melts in a cherry red heat. The compound is destroyed on exposure to the air; it effervesces with water, and more violently with the acids. This alloy is difficult to form in consequence of the volatility of the potassium.†

The alloy of zinc and sodium is of a bluish gray colour, brittle, and composed of small laminæ; it is nearly as fusible as the alloy with potassium. It comports itself with the air, water, and the acids, like the above alloy.‡

Zinc forms an alloy with iron, but it is difficult to make the compound. It is white, hard, and somewhat malleable. When thin plates of iron are immersed in melted zinc, a permanent alloy is formed.

Zinc is an article of much value in commerce, as it constitutes an essential ingredient of brass. It has been proposed also to substitute it for lead and copper in covering houses and ships, in the formation of pipes for the conveyance of water, and in the fabrication of culinary utensils. It is probable however that it will never be extensively used for these purposes, as it oxidizes with facility; and the French chemists affirm, that it is acted upon by water, which it renders unwholesome.*

Zinc is a useful metal to the chemist. From its strong attraction for oxygen it is employed in analytical researches for the purpose of precipitating other metals from their acid

* System of Chemistry, vol. ii p. 572. 5th ed.

† Gay-Lussac and Thenard, *Recherches*, t. i. p. 221.

‡ Ibid.

Ibid. p. 243.

§ *Annales de Chimie*, t. lxxxvi. p. 113.

combinations, and it is always used in conjunction with copper in the formation of the voltaic battery.

SECTION III.

Of Tin.

DLXXI. Tin has been known from time immemorial. Its ores, which are of two kinds, the oxide and sulphuret. do not appear to be very common; they are found in Cornwall in England, in Galicia in Spain, in Malacca, and in South America.

Tin is of a fine white, and in brilliancy inferior only to silver. It is malleable, but neither very ductile, nor tenacious, a wire of this metal $\frac{1}{16}$ of an inch in diameter supporting a weight of only 50 pounds. It is flexible, and when bent, if in thin leaves, produces a peculiar crackling noise. Its taste is disagreeable, and when rubbed between the fingers, it emits a peculiar odour. Tin is one of the lightest of the common metals, its specific gravity in its usual state being 7.291; and when beaten 7.299. It is inferior to most of the other metals in hardness; for its polished surface may be scratched by most of them, and it is easily cut with a knife, and filed. Exposed to heat, it melts at the temperature of 442° Fah. and by slow cooling may be obtained regularly crystallized in rhomboidal prisms. If the temperature be increased greatly above its melting point, it takes fire and burns with flame. Before the oxygen, or oxy-hydrogen blow-pipe, it consumes with an intensely brilliant violet coloured flame.

Oxides of Tin.

DLXXII. 1. *Protoxide* may be obtained by exposing tin to heat in contact with the air; but it is procured in a purer state by dissolving tin in muriatic acid by the aid of heat, and adding to it an excess of potash, or pure ammonia, oxide of tin precipitates, which is to be collected and dried. It is of a

blackish gray colour, insoluble in water, indecomposable by heat, and soluble in acids and alkalies. Exposed to heat it takes fire, absorbs more oxygen, and is converted into peroxide of tin. It is composed of 100 of tin, and 13.55 of oxygen; its constitution may therefore be stated as follows.

			Prop.					
Tin	-	-	1	-	-	100	-	89.07
Oxygen	-	-	1	-	-	13.55	-	11.93
			<hr/>					<hr/>
			2					100.00

The representative number of tin is thus 56, and that of its protoxide 63.5.

2. *Peroxide.* When nitric acid is poured upon tin, a violent action takes place, the acid is decomposed, and yields so much oxygen to the metal, that it becomes insoluble and precipitates in the form of a dull white powder. This, when dried and exposed to a strong heat, constitutes peroxide of tin. It may likewise be formed by heating tin or the protoxide strongly and for some time in contact with the air. This oxide is white, fusible, insoluble in water, but soluble in the alkalies, and in sulphuric acid; indecomposable by heat, but reducible by voltaic electricity. It consists of 100 of metal united with 27.10 of oxygen, and its constitution may be thus stated.

			Prop.					
Zinc	-		1	-	-	100	-	78.68
Oxygen	-	-	2	-	-	27.10	-	21.32
			<hr/>					<hr/>
			3					100.00

And it will be represented by $56 + 15 = 71$.

This oxide is found in nature; it is called tin stone, and is the only ore worked for the extraction of the metal. It is often crystallized in the form of a rectangular, 4-sided prism, terminated by 4-sided pyramids; but it is often truncated or

bevelled on the edges. Its colour varies from blackish brown to grayish white, and has been supposed to depend upon the presence of oxide of iron. It is brittle, but so hard as to strike fire with steel. Its lustre is vitreous. It is often found in twin crystals or in groupes. Its specific gravity is 6.9, and it occurs only in primitive rocks.

The oxides of tin combine with water and form hydrates.

Chlorides of Tin.

DLXXIII. Dr. J. Davy has shown that tin combines with two proportions of chlorine and forms two chlorides.*

1. *Chloride or proto-chloride.* It is formed by distilling together a mixture of an amalgam of tin and calomel; or by evaporating to dryness the muriate of tin, containing the protoxide, and melting the mass out of contact with the air. It is a semi-crystalline solid of a gray colour, and resinous lustre and fracture, fusible below redness, but decomposable above it. When brought into contact with water, it decomposes it, and is converted into muriate of tin.

Dr. J. Davy states its composition at 100 of tin, and 60.71 of chlorine. Hence it consists of

		Prop.					
Tin	-	1	-	100	-	-	62.22
Chlorine	-	1	-	60.71	-	-	37.78
		<hr/>					<hr/>
		2					100.00

Its representative number will be 56+33.5 or 89.5.

2. *Perchloride.* When filings of tin are thrown into dry chlorine, they take fire, burn with a white light, and form a clear, volatile liquid, which is perchloride of tin. It is usually prepared by distilling a mixture of an amalgam composed of 5 parts of tin and 1 of mercury, with an equal weight of corrosive sublimate; or according to Sulze, 6 parts tin, 1

* Philosophical Transactions for 1812, p. 177.

mercury, and 33 of corrosive sublimate.* The beak of the retort is connected with a large globular receiver, kept cold. The heat should at first be gentle. A colourless liquid passes over, and then a great quantity of white and dense fumes rushes into the receiver, which soon condense into a fuming liquid. Corrosive sublimate is a per-chloride of mercury, and in this process its chlorine is transferred to the tin. The product must be kept in a close vessel. This is the old *fuming liquor of Libavius*. Its constitution was first determined by Sir H. Davy.

It is a colourless and transparent liquid, which gives off dense, white, suffocating fumes on exposure to the air. It probably decomposes its aqueous vapour. Mixed with water in the proportion of 1 of water to 3 of the chloride, it forms a solid crystalline mass. Exposed to the air it attracts aqueous vapour and crystallizes. According to Dr. Davy it acts with violence on oil of turpentine. He found it composed of 100 of tin, and 140.44 of chlorine. These numbers by no means agree with the theory of definite proportions, for if it be considered with Sir H. Davy as a compound of 2 proportions of chlorine and 1 of tin, it will consist of

	Prop.					
Tin	-	1	-	-	100	- 45.17
Chlorine	-	2	-	-	121.42	- 54.83
		<hr/>				<hr/>
		3				100.00

and will be represented by 56 + 67, or 123.

Iodide of Tin.

When tin and iodine are heated together, they combine and form an orange yellow compound, fusible, and capable of decomposing water, forming oxide of tin and hydriodic acid, which constitute hydriodate of tin. The elements of this salt are retained in combination, provided the quantity of

* Thomson's System, vol. i. p. 435. 5th ed.

water have not been large, and the compound has a silky lustre and a yellow colour; but if much water be employed, oxide of tin is precipitated, and hydriodic acid remains in solution.*

Phosphuret of Tin.

DLXXIV. This compound may be formed by projecting small pieces of phosphorus in succession upon melted tin; or by heating together equal weights of tin filings and phosphoric acid. This phosphuret is silvery white; its structure is foliated, and it is so soft as to be cut with a knife, and flattened under the hammer. Its filings resemble those of lead. When heated, the phosphorus takes fire, and the compound is destroyed. It consists of 100 of tin combined with from 15 to 20 parts of phosphorus.

Sulphurets of Tin.

DLXXV. Tin combines with two definite proportions of sulphur, and forms two compounds, the sulphuret and bi-sulphuret.

1. *Sulphuret.* It is produced by mixing sulphur and tin together, melting them in a crucible, reducing the mass to powder, mixing it again with sulphur, and heating the mass to drive off the redundant sulphur. It has the colour and lustre of lead, and is capable of crystallizing in cubes. By the action of muriatic acid it is converted into oxide of tin, and sulphuretted hydrogen gas is evolved. It consists of 100 of metal, and 27.19 of sulphur, or of

	Prop.					
Tin	-	1	-	100	-	78.63
Sulphur	-	1	-	27.19	-	21.37
		<hr/>				<hr/>
		2				100.00

Its representative number is $56 + 15$, or 71.

* Gay-Lussac—Memoir on Iodine—Annals of Philosophy.

2. *Bi-sulphuret*. Twelve parts of tin are melted in a crucible, and 3 parts of mercury are added ; the mass is then rubbed to a powder and intimately mixed with 7 parts of sulphur in powder, and 3 parts of muriate of ammonia. This mixture is put into a matrass, of which it shall occupy one half, and exposed to heat so long as white vapours continue to exhale. The temperature is then to be increased for a time ; at the end of the process, sulphuret of mercury and muriate of tin will be found condensed on the upper part of the vessel, and the bi-sulphuret will be formed at the bottom. It then constitutes what is called in the arts *aurum musivum*, or *mosaicum*, *mosaic gold*. It was formerly supposed to be a sulphuretted oxide of tin, but Dr. J. Davy has proved that it is a sulphuret. If too high a temperature be employed, common sulphuret of tin only is formed.

The bi-sulphuret, when well prepared, is in the form of light flakes, of a beautiful golden yellow colour, and metallic lustre. It is insoluble in water, alcohol, and nitric and muriatic acids, but is decomposed by nitro-muriatic acid. By heat it loses a portion of sulphur, and is converted into the sulphuret of tin. It is dissolved by solution of potash, and this solution, which is green, is decomposed by the acids. It contains double the quantity of sulphur which exists in the sulphuret. It is composed therefore as follows,

	Prop.						
Tin	-	1	-	-	100	-	64.78
Sulphur	-	2	-	-	54.38	-	35.22
		<hr/>					<hr/>
		3					100.00

Its representative number is $56 + 30$, or 86.

It is employed in the arts to give to various ornamental articles the colour and appearance of bronze, or of gold.

Salts of Tin.

DLXXVI. The salts of tin, or rather the salts in solution, are not permanent. This metal has a strong attraction for oxygen, and even in the state of protoxide, absorbs it with some rapidity ; hence it passes easily to the state of peroxide, which has a much feebler attraction for the acids, and is for the most part precipitated.

Muriate of tin. When tin, in filings or shavings, is boiled in muriatic acid, a solution of a brownish colour is formed, which, after a while, deposits crystals in the form of small and slender prisms, soluble in water, and deliquescent. By the affusion of water it is partially decomposed, a submuriate being precipitated, and a super-muriate remaining in solution. This muriate is likewise formed by the action of chloride of tin on water.

When its solution is exposed to the air, it absorbs oxygen, and the salt passes to the state of permuriate.

The muriate of tin decomposes many of the salts of the metals which are in the state of peroxides, it attracts one proportion of their oxygen, and converts them into protoxides, while it is itself changed to peroxide.

Nitrate of tin. Nitric acid, slightly diluted with water, acts with great violence on tin, and the metal becomes so highly oxidized that it does not combine with the acid. But if the acid be considerably diluted, be kept cold, and the tin be added by small portions at a time, a solution takes place, but it cannot be evaporated without decomposing the salt, as the oxide attracts oxygen and forms peroxide, which precipitates.

Nitro-muriate of tin. The solution of tin in this liquid may be effected by the same means as are employed in the formation of the nitrate. The acid dissolves nearly half its weight of tin, forming a brown coloured translucent liquid, which, on being allowed to rest for some time, becomes gelatinous and even solid. It is decomposed by half its weight of water, which separates a quantity of oxide of tin. When the

liquid solution is heated, an effervescence takes place, peroxide of tin is formed, and the solution on cooling becomes gelatinous.

The nitro-muriate of tin, or rather its solution, is employed by the dyer as a mordant to fix the colour on the cloth. It also heightens the scarlet dyes from cochineal.

The other salts of tin are of little consequence.

During the solution of tin in muriatic acid, hydrogen gas of a peculiar odour, resembling that of arsenic, is produced. It has been supposed to be owing to the presence of that metal, but Bayen has proved that it is not the case, for in the tin of commerce there is not often any arsenic existing, and when it is found in it, the proportion is so small that it can have no influence in producing this odour.

The oxide of tin is soluble in solutions of the pure alkalis, and again precipitated by the acids; whence it was once supposed by some chemists, that it performed the functions of an acid, and was called the *stannic* acid. But this opinion has not been verified, and the power of these oxides to combine with the acids, is adverse to this hypothesis.

Alloys of Tin.

DLXXVII. When tin and potassium are heated together, they enter into combination, and at the same time give out a feeble light. The alloy is whitish, brittle, and fusible, and is decomposed by exposure to the air, or immersion in water.

The alloy of tin and sodium is less fusible than the above.*

Tin and zinc may be easily combined by fusion. The alloy is much harder than zinc, much stronger than tin, and still ductile. This alloy, it is said, is often the principal ingredient in *pewter*.†

The alloy of tin and iron is very valuable, as it constitutes the substance of *tin plate*. The mode of forming this com-

* Gay-Lussac and Thenard, *Rechères*.

† Thomson's System, i. p. 441. 5th ed.

pound is to dip thin plates of iron, which have been thoroughly cleaned, into melted tin, the surface of which is protected from the air by a thin film of melted tallow. The iron is penetrated by the tin, and an alloy is formed, which is white, less liable to rust, and equally pliable as the iron itself. Alloys of these two metals, differing in their proportions, may likewise be formed by melting them together.

Tin is a valuable metal, and is applied to many useful purposes.

SECTION IV.

Of Manganese.

DLXXVIII. This metal, in consequence of the difficulty of obtaining it, is not applied to any useful purpose, but its oxide is employed in some of the arts. Manganese in the form of peroxide is found in various parts of the world. It is the principal ore of this metal ; it exists likewise in combination with carbonic acid and silex ; and with sulphur, in the black ore from Transylvania. It was first obtained in its metallic state by the Swedish chemist Gahn, by mixing the black or peroxide in fine powder with oil, putting the paste in the form of a ball into a crucible lined with charcoal, filling the whole with powder of the same substance, and exposing it for some time to the highest heat of a forge or wind furnace. The melted manganese is found at the bottom of the crucible in small globules or buttons. In this state however, it is combined with iron which it retains with great obstinacy, and various processes have been pursued to separate them. By dissolving the black oxide with a little sugar in nitric acid and adding carbonate of soda, carbonate of manganese is precipitated, which may be subsequently reduced. The best method perhaps is that of Mr. Hatchett, which consists in adding ammonia to its solution in muriatic acid, which precipitates the iron, but not the manganese. The ammonia should be in slight excess.

Manganese, when pure, is a metal of a grayish white colour, but of inconsiderable lustre ; it is hard, brittle, of a granulated texture, and of a specific gravity equal to 8.013. It is destitute of taste and smell ; and is neither ductile, nor malleable. When obtained immediately from the black oxide it is attractable by the magnet, but this property is owing to the presence of iron.

It requires for its fusion a temperature higher than that of iron ; its melting point being placed at about 160° of Wedgewood.

Oxides of Manganese.

DLXXIX. When metallic manganese is exposed to the air, its particles lose their cohesion, the mass cracks, falls to pieces, and passes from light gray through a succession of colours to deep brown or black. These changes are owing to the absorption of oxygen.

Considerable uncertainty still exists relative to the number of proportions of oxygen with which this metal is capable of uniting. Sir H. Davy makes but 2 oxides, the olive and the brown ;* Berzelius enumerates four ;† Dr. John three ;‡ Dr. Thomson but two ;§ and M. Gay-Lussac three.|| Arfredson, a Swedish chemist, is stated to have proved the existence of 3 oxides. M. Thenard admits 3 oxides of manganese, on the authority of Gay-Lussac, and assigns the proportions of oxygen according to Berzelius.¶ These are in the ratio of 28, 42, 56, or 1, $1\frac{1}{2}$, 2, or 2, 3, 4. So that the peroxide must contain 4 proportions of oxygen, and the representative number of manganese should be derived from a protoxide, which contains 14 of oxygen + 100 of metal, but which has not been discovered. There is no doubt of the existence of 2 oxides, while some degree of uncertainty re-

* Elements, p. 367.

† Annals of Philosophy, vol. iii. 359.

‡ Annals of Philosophy, iii. 417. § System, i. p. 403, 5th ed.

|| Annales de Chimie et de Physique, t. i. p. 38.

¶ Traité de Chimie, ii. p. 69, 2de. ed.

mains respecting the others ; at present therefore it would be safest to consider the olive substance as a protoxide, and the black as a peroxide.

1. The *protoxide of manganese* may be formed by precipitating its nitric, muriatic, or sulphuric solution by potash, washing the precipitate with boiled water, and drying it in close vessels. The white precipitate first formed is a hydrate. When the protoxide is first made, its colour is an olive-green, which, on exposure to the air, becomes flea-brown, and finally red-brown. When heated, the olive oxide takes fire, absorbs oxygen, and is converted into peroxide. It absorbs oxygen from the air, and dissolves in acids without effervescence.* From calculations founded on the composition of the sulphate, and carbonate, the proportion of oxygen in this oxide is stated by Dr. Thomson at $28.75 + 100$ of metal.† Hence the representative number for manganese is 26, and that of the protoxide $26 + 7.5$, or 33.5.

2. *Peroxide.* This oxide is what is commonly known in commerce by the name of manganese. It is found native, of a dark steel-gray colour, of a radiated structure, and of a metallic lustre. It is inferred to contain double the quantity of oxygen which exists in the protoxide, and will therefore consist of $100 + 57.5$ of oxygen ; and may be represented by $26 + 15$, or 41. Exposed to heat gradually raised to redness, a quantity of water first passes off, and then oxygen gas nearly in a state of purity. It dissolves with effervescence in the acids, for it is partially decomposed by them, and converted into protoxide, oxygen being disengaged.

Chloride of Manganese.

DLXXX. Manganese, introduced in chlorine, takes fire and burns brilliantly into a chloride. The same compound may be formed by evaporating its muriatic solution to dryness, and exposing the mass to a red heat in a glass tube. This

* Sir H. Davy. Elements, p. 368.

† System, i. p. 404.

chloride is of a light pink colour, semi-transparent, and of a lamellated structure. When secluded from the air it fuses at a red heat, but is decomposed in open vessels. On exposure to the air it deliquesces and forms muriate of manganese, and the same effect is produced by putting it into water. According to Dr. J. Davy's analysis, it consists of 46 of manganese, and 54 of chlorine. Its theoretical composition will be

	Prop.							
Chlorine	-	1	-	-	100	-	-	56.29
Manganese	-	1		-	77.6	-	-	43.71
		<hr/>						<hr/>
		2						100.00

and it may be represented by $33.5 + 26$, or 59.5 .

Manganese combines with carbon, forming a compound of a steel-gray colour, brittle, and crystallizable in thin plates.

The phosphuret of manganese is white, brittle, of a granulated texture, and more fusible than manganese. Heated in contact with the air, the phosphorus takes fire, and the metal becomes oxidized.

Salts of Manganese.

DLXXXI. Nitrate of manganese. This salt may be formed by the action of the acid on the black oxide, provided a little sugar be present, which converts the peroxide into the protoxide, by taking 1 proportion of its oxygen. Dr. John obtained the nitrate with some difficulty in the form of prismatic needles, longitudinally channelled; they were white, semi-transparent, and had a bitterish taste. They are exceedingly deliquescent, and fusible; soluble in alcohol, and the solution gives to combustible bodies the property of burning with a green coloured flame. This solution is decomposed by the alkaline oxalates, and phosphates.*

Carbonate of manganese, formed by adding solution of carbonate of potash to solution of nitrate, or sulphate of man-

* Annals of Philosophy, vol. iii. p. 413.

ganeses, is in the form of a yellowish white powder, insipid, insoluble in water, unalterable in the air, and composed of carbonic acid 37.93, protoxide of manganese 62.07.

Muriate of manganese. This salt may be formed by dissolving the protoxide, or the carbonate, in muriatic acid. The solution has a rose colour. When crystallized, the salt, according to Dr. John, appears in the form of long 4-sided tables, terminated by two planes; they are of a rose-red colour, semi-transparent, of a sharp and somewhat saltish taste, deliquescent, and very soluble both in water and alcohol, tinging the flame of the latter red. It consists, according to the same chemist, of 20.04 parts of acid, 38.50 of protoxide, and 40.46 of water.

Sulphate of manganese. It is well known that when sulphuric acid and black oxide of manganese are heated together, a quantity of oxygen gas is disengaged. It appears that the acid has an affinity for the protoxide, but not for the peroxide, and it converts the latter into the former, and then combines with it to produce a sulphate. When water is added to it, a reddish coloured solution is obtained, which is acid, and forms crystals with great difficulty. Evaporated to dryness, it affords a red coloured mass, soluble in water, and decomposable by the alkalies, which precipitate the oxide of a red colour.

This compound is considered by chemists as a *per-sulphate* of manganese.

The *proto-sulphate* may be obtained, according to Dr. John, by dissolving the carbonate in sulphuric acid. Its taste is slightly sweetish and astringent, and it crystallizes in rhombs, or 4-sided prisms, which are permanent in the air, and soluble in water, but insoluble in alcohol.

Sulphate of manganese may likewise be formed by bringing sulphurous acid into contact with peroxide of manganese; for the latter by losing 1 proportion of oxygen, is changed to the protoxide, and the former by gaining it, is converted into sulphuric acid.

Manganese with Potash.

DLXXXII. When pure potash and black oxide of manganese in fine powder are melted together in a crucible, a substance is obtained, which, from the curious properties it exhibits, has been called Chameleon Mineral. M. Chevreul infers that there are two compounds, one green and the other red. The compound may be formed, according to Chevillot and Edwards, of equal weights of pure potash, and pure oxide of manganese; the usual method is to mix 1 part of finely powdered black oxide, with 3 or 4 parts of nitre, and to project the mixture, by small portions at a time, into a red hot crucible; a green coloured mass is obtained, which should be powdered while hot, and be preserved from the air. When a little of this compound is put into water, it dissolves, and during the solution the colour changes from a green, through the suite of colours constituting the coloured rings, to a red. The red compound was obtained crystallized in needles from 2 to 8 lines in length, permanent in the air, and soluble in water, by Chevillot and Edwards, by dissolving a compound of equal weights of potash and the oxide in water, decanting, and rapidly evaporating the solution, until it began to deposit red crystals. When dissolved in water, it communicated to it a fine red colour.*

Various explanations have been given of the phenomena presented by the chameleon mineral during its solution in water, but in the present state of our knowledge, none of them is satisfactory.

Alloys of Manganese.

DLXXXIII. Metallic manganese is obtained in such small quantities, and it is so infusible, that its alloys are formed with difficulty, and have not been extensively examined. It is capable of uniting with tin, and even with zinc. But its most common alloy is that with iron, with which it is very often found associated in nature. Indeed from the appearance

* Annals of Philosophy, vol. xii. p. 18,

of the ores of manganese, and the quantity of iron they afforded, the former were for a long time ranked with those of the latter. It is very difficult to separate them from each other, and various processes have been proposed, of which, that of Mr. Hatchet is perhaps the best. A solution of the ore of manganese in muriatic acid, is to be diluted with 3 or 4 pints of pure cold water; liquid ammonia is then to be dropped in until the acid be perfectly neutralized; then add a few more drops, and separate the oxide of iron by filtration.*

The alloy of manganese and iron, when artificially formed, is white and brittle. Bergman affirmed that he detected manganese in steel; and Berzelius asserts that it constitutes an essential part of cast iron.

Uses of Manganese.

DLXXXIV. This metal is never employed in the arts; but the peroxide is used in bleaching, for the purpose of obtaining chlorine; and in glass-making, either to communicate or to destroy colour. When melted in small proportion with the other ingredients, it gives to the vitreous compound a beautiful amethystine colour. But if the glass contain protoxide of iron, from which it acquires a tinge of green more or less deep, the addition of oxide of manganese will render it colourless and transparent. The protoxide of iron attracts oxygen from the manganese, and is converted into peroxide, in which state, it either does not combine with the other ingredients, or if it does, is incapable of colouring them, while the peroxide of manganese, in losing a portion of its oxygen, is reduced to a protoxide, which forms with the glass a colourless compound. Hence if the oxide of manganese be redundant, the glass assumes a tint of purple; if deficient in quantity, it retains a shade of green.

The native oxide is sometimes intentionally mixed with the other ingredients of pottery ware, and gives to the article, when baked, a black colour.

* Annals of Philosophy, vol. ii. p. 343.

DIVISION IV.

Metals which absorb oxygen at temperatures below redness ; but which are incapable of decomposing water either above or below ignition.

This division includes 14 metals, six of which are acidifiable, viz. Arsenic, Molybdena, Chrome, Tungsten, Columbium, and Selenium. The properties of these will be first described.

SECTION I.

Of Arsenic.

DLXXXV. To obtain this metal, the arsenic of commerce is to be mixed with an equal weight of black flux or charcoal, and put into a crucible, to which another crucible is to be luted, and the mixture is then to be exposed for some time to a dull red heat. When the apparatus is cold, the metallic arsenic will be found in the upper crucible.

It is a metal of a bluish-gray colour, of considerable lustre, and crystallized in tetraedra, or octaedra. It is of a striated texture, soft, brittle, and easily reduced to powder. Its specific gravity is about 5.76. Arsenic is very volatile, and when exposed to heat it ascends in vapour, without previously melting, at the temperature of 388° . When volatilized in the air, it passes off in white smoke, which has a peculiar odour, somewhat resembling that of garlic.

Arsenic with Oxygen.

DLXXXVI. Arsenic has a strong attraction for oxygen. On exposure to the air its brilliant surface soon becomes tarnished, it then turns black, and falls into powder. When heated the combination goes on more rapidly, and it forms a white powder, which is volatile, and passes off in fumes. If the temperature be augmented, it takes fire and burns with a pale blue flame.

The white substance formed by heating arsenic in the air, is oxide of arsenic, or what in commerce is called white arsenic. The metal however is capable of combining with an additional proportion of oxygen, and of forming another compound.

1. Oxide of arsenic, which is obtained in the large way by sublimation from the ores of other metals, is a white, brittle, and compact substance, which, when recently formed, has a glassy appearance, but after exposure for some time to the air, assumes the character of enamel. Its taste is acrid, and it is one of the most violent of the poisons. It will produce sickness even by tasting without swallowing it. When volatilized it has the aliaceous or garlic odour.

It is soluble, according to Klaproth, in water ; 1000 parts of cold water dissolving $2\frac{1}{2}$ parts, and the same quantity of boiling water $77\frac{3}{4}$ of the oxide.* From the last solution it is deposited in crystals of an octaedral, or tetraedral form. It combines with the alkalies, and slightly reddens infusion of litmus ; hence it has by most chemists been considered as an acid, and has been called the *arsenious*. It is likewise soluble in 70 or 80 parts of alcohol, and in oils. It sublimes at 385° Fah. and its specific gravity is about 8.706.

2. *Peroxide of arsenic. Arsenic acid.* When arsenic is combined with an additional proportion of oxygen, its acid properties are fully developed. The compound may be obtained by dissolving 2 parts of arsenious acid in 7 parts of muriatic acid by the aid of heat, adding to the solution $3\frac{1}{2}$ parts of nitric acid, and distilling so long as red fumes are disengaged ; 1 part of oxide of arsenic is then added, and after it is dissolved, $1\frac{1}{2}$ parts of nitric acid are poured into the solution, which is then to be distilled to dryness in a red heat. This is Scheele's process. It may be procured likewise by dissolving the white oxide in nitric acid, and distilling to dryness, but the process is long. It is a white substance, very soluble in water, and imparting to it a very acid taste. The

* Annals of Philosophy, iv. 132.

solution does not crystallize when evaporated, but when dry it forms a white mass, which may be melted into transparent glass. It is not volatile on exposure to heat. But when the temperature is high, it loses a portion of its oxygen, and is changed to arsenious acid. It combines with salifiable bases and neutralizes their properties. This acid is as poisonous as the white oxide.

It appears by the experiments of different chemists, and particularly of Dr. Thomson,* that the oxygen in arsenious acid, is to the oxygen in arsenic acid as 3 to 5; and the latter states the composition of the arsenious acid at 100 of arsenic + 31.6 of oxygen; and of arsenic acid at 100 + 52.631.†

Hence, supposing arsenious acid to contain 2 proportions of oxygen, the number for arsenic will be 47, and that for the white oxide 62.

Chemists have generally regarded the black powder which forms on arsenic exposed to the air, as a mixture of the metal with the arsenious acid or white oxide. If this were the case however, the colour should be gray, and in the course of time the whole should become white, which is not the fact. It would seem, therefore, that it should be considered as a determinate compound. Berzelius regarded it as a distinct oxide, containing 8.07 parts of oxygen; and M. Thenard has described it as a protoxide of arsenic.‡ This opinion is not improbable, particularly when the high acid properties of arsenic acid are taken into view. Hence if the opinion of Berzelius be adopted, that it contains $\frac{1}{4}$ part of the oxygen which exists in arsenious acid, it will consist of 100 of metal, and 8 of oxygen.

Chloride of Arsenic.

DLXXXVII. Arsenic in powder thrown into chlorine gas burns brilliantly with a white light, and forms thick white

* Annals of Philosophy, vol. iii. p. 93.

† System, vol. i. p. 297. 5th ed.

‡ Traité de Chimie, t. ii, p. 84. 2de ed.

vapours, which condense into a liquid, possessing the properties of *butter of arsenic*. This compound may be formed by distilling in a retort 6 parts of corrosive sublimate and 1 of metallic arsenic, with a gentle heat; a liquid is obtained in the receiver, which is transparent, of an oily consistence, very volatile, and emits acrid white vapours on exposure to the air. It absorbs water from the air, but is decomposed by mixture with it. By the aid of heat it dissolves sulphur and phosphorus, which are precipitated as it cools. According to Dr. John Davy it consists of 39.52 of arsenic, and 60.48 of chlorine.* By Sir H. Davy it is considered as a compound of 1 proportion of metal, and 2 proportions of chlorine.† If it be so considered, and if arsenic be represented by 47, its composition may be stated at 41.17 of arsenic, and 58.83 of chlorine; and it will be represented by $47 + 67$, or 114.

This chloride, or *butter of arsenic*, as it was formerly called, is corrosive, and has been applied by surgeons as a caustic.

Iodide of Arsenic.

DLXXXVIII. Has a dark purple colour, and the properties of an acid; is soluble in water, but not precipitated by potash. Nitrate of silver produces in the solution a precipitate of a sulphur yellow colour.‡

Arsenuretted Hydrogen.

DLXXXIX. When arsenic is presented to nascent hydrogen, they combine and form arsenuretted hydrogen gas. It may be prepared, 1. By mixing zinc filings, arsenic, and diluted sulphuric acid. 2. By digesting an alloy of 15 parts of tin with 1 of arsenic in muriatic acid. 3. By boiling powder

* Philosophical Transactions for 1812, p. 186.

† Elements, p. 455.

‡ Ruhland. Thomson's Chemistry, 5th ed. vol. i. p. 298.

of metallic arsenic in a concentrated alkaline ley. The gas may be caught over water.

It is a permanently elastic fluid, of a fœtid, alliaceous odour, incapable of supporting combustion, and of a specific gravity equal to 0.5293. It is not absorbed by water, nor does it change vegetable colours. When inflamed, it consumes with a blue flame and disagreeable odour, and metallic arsenic is deposited. Two parts of the gas with 3 of oxygen explode when fired, and the products are water and arsenious acid. Mixed in equal parts, the explosion is less violent, but the light is more vivid. It requires for its combustion 0.72 of its bulk of oxygen. Added to chlorine, the temperature rises, there is a diminution of volume, and arsenic is deposited. It is inflamed by concentrated nitric acid, and copious red fumes are produced. From the modes in which arsenuretted hydrogen is obtained, it is almost necessarily mixed with variable proportions of pure hydrogen; hence the analyses of chemists differ in their results. According to Dr. Henry, 1 cubic inch contains $\frac{1}{4}$ of a grain of arsenic.

A solid hydruret of arsenic may likewise be formed. When arsenic is made the negative pole of the voltaic battery and is immersed in water, it becomes dark coloured, a brown powder separates, and according to Dr. Murray, less hydrogen is given off than when a wire of platina is used.*

The same compound appears to have been formed by Gay-Lussac and Thenard during the action of an alloy of potassium and arsenic on water; it appeared in flocculi of a chestnut brown colour.†

Arsenuretted hydrogen gas is fatal to animal existence; and poisonous even when breathed in small quantities. Gehlen, a celebrated chemist of Munich, lost his life in making experiments with it. He accidentally inhaled some of it, and died from the effects of it in 19 days after.‡

* System of Chemistry, vol. iii. p. 436, 4th ed.

† *Rechères*, t. i. p. 232.

‡ *Annals of Philosophy*, vol. viii. p. 403.

Phosphuret of Arsenic.

DXC. This compound, formed by heating together in a retort equal parts of these elements, or phosphorus with oxide of arsenic, is a black and brilliant mass, which is decomposed on exposure to the air, and burns on red hot coals.

Sulphuret of Arsenic.

DXCI. When metallic arsenic and sulphur are exposed to heat in a covered crucible, they combine, and form an uniform mass of fine red colour, a vitreous aspect, and a conchoidal fracture. It is a sulphuret of arsenic. It is insipid, and insoluble in water, and by no means so poisonous as arsenic with oxygen. Hence the Chinese are said to make cups of it, which give an emetic property to liquids which are allowed to remain in them. This is also a native production, and is found in various parts of the world in crystalline semi-transparent grains, or prisms, of a beautiful scarlet colour, and of a specific gravity amounting to 3.33. This sulphuret of arsenic is known in the arts by the name of *Realgar*.

If this combination be formed without the aid of heat, a yellow coloured substance, called *orpiment*, is the result. It may be formed by pouring a recently made solution of sulphuretted hydrogen in water, into a solution of arsenic in muriatic acid, the liquids become turbid and deposit a yellow precipitate. This compound likewise exists native, of a beautiful straw yellow, crystallized in thin and delicate laminae, semi-transparent, and of a lustre between vitreous and resinous. It was once supposed that the difference in colour between realgar and orpiment depended upon a difference in the proportion of the elements, arsenic and sulphur, but Haüy found their primitive forms to be the same, and Laugier proved that the quantity of sulphur in both was equal. The sulphuret of arsenic, according to his experiments, consist of 58 of arsenic, and 42 of sulphur. If it be considered as containing 2 proportions of sulphur, it will be composed of

	Prop.					
Arsenic	1	-	-	100	-	62.05
Sulphur	2	-	-	63.38	-	38.95
	<hr/>					<hr/>
	3					100.00

and may be represented by $47 + 30$, or 77 .

The combinations of arsenic and oxygen have this peculiarity, that they perform the functions both of acids and alkalis; for the most part, however, the acid property predominates, and the compounds which they form with the salifiable bases are more numerous and more perfect than those which result from their union with acids.

Fluoric, phosphoric, and boracic acids dissolve the white oxide, and form crystalline salts or compounds in the state of powder.

Arsenic decomposes nitric acid with facility, and the oxide is dissolved provided the acid be diluted. The solid salt may be obtained by evaporation. Oxide of arsenic, frequently distilled with nitric acid, decomposes it, seizes a portion of its oxygen, and is converted into arsenic acid.

Sulphate of arsenic, produced by boiling the acid on metallic arsenic, or its oxide, is in the form of crystalline grains, sparingly soluble in water, and decomposable by heat.

Arsenic, heated in liquid muriatic acid, becomes oxidized at the expense of the water, and arsenuretted hydrogen is disengaged. It dissolves $\frac{1}{3}$ of its weight of the oxide without effervescence; the solution has the colour of muriatic acid, and as it cools, crystalline grains are deposited. If this compound be considered as a chloride, the hydrogen, in the first case, must come from the muriatic acid.

Arsenious Acid with Bases.

DXCII. Arsenious acid combines with the alkalies both in the dry and humid way. When exposed to a red heat it unites with potash in the proportion of 2 to 1; and with soda, in the proportion of 3 to 1; and in both cases the

compounds may be subjected to a much greater heat without decomposition, than is required for the sublimation of the arsenious acid. These compounds are soluble in water ; and they may be formed directly by boiling arsenious acid in solutions of the alkalies, the solutions when concentrated being thick and tenacious, of a brown colour, and fœtid. These compounds are partly decomposed by the acids.* When added to metallic solutions, *arsenites* are formed in many cases, the colours of which vary with the nature of the metal.

Arsenic Acid with Bases.

DXCIII. If carbonate of potash be added to arsenic acid until effervescence ceases, a liquid is obtained, which, by its action on vegetable colours, appears to contain an excess of base. It is incapable of crystallizing, and when evaporated to dryness the mass is deliquescent.

If the excess of base be saturated with arsenic acid, a salt is the result, which may be considered as an arseniate, or *binarsenate*.

Arsenate of potash. It may be formed by projecting into a red hot crucible, a mixture of equal weights of oxide of arsenic and nitre, and heating it until it cease to give off red fumes. It is then to be dissolved in water, and crystallized. Its form is a 4-sided prism, long, transparent, soluble in water, and changing vegetable blues to a red. It is not decomposed by lime or magnesia.

Arsenate of soda crystallizes in hexaedral prisms, and exhibits properties analogous to those of the arseniate of potash. Both of these salts are highly poisonous. Arsenic acid likewise combines with the oxides of the metals of the first and second divisions, and forms compounds, which, for the most part, are insoluble, or nearly so, in water, and uncrystallizable.

* Bergman.

It unites with both oxides of iron and forms peculiar salts. With the protoxide it constitutes a salt in the state of powder, and insoluble in water. The arseniate of iron is found native, crystallized in cubes, of a dark green colour, of a specific gravity equal to 3, and composed of 38 acid, 52 oxide, and 12 of water.*

The combination of arsenic acid with the peroxide of iron is formed by adding arseniate of ammonia to solution of red sulphate of iron. Its colour is brownish red, and it is insoluble.

Arsenic acid likewise unites with the oxides of zinc, tin, and manganese.

Alloys of Arsenic.

DXCIV. Arsenic exposed to heat with iron, combines with it and forms an alloy which is white, brittle, and of a crystalline structure.

Zinc unites with arsenic, but the properties of the compound have not been examined.

The alloy of tin and arsenic is white, brittle, harder and more sonorous than tin, and in the ratio of 1 of arsenic to 15 of tin, is crystallizable in large plates like bismuth.

Uses and Tests of Arsenic.

DXCV. The oxide of arsenic, or arsenious acid, is employed in the fabrication of glass, which it renders transparent, by its attraction for foreign substances and its volatility, when used in small proportions, but opaque or opal coloured when in large proportion. Its sulphuret, realgar or orpiment, is used as a pigment, and in some processes of dyeing. The oxide is likewise made use of to poison animals, whence is derived its common name of *Ratsbane*. It constitutes an article of the materia medica, and is occasionally prescribed as a powerful tonic and alterative. It has been most celebrated in the cure of intermittent fever.

* Chenevix.

From the energy of its action on the animal body, the arsenic of commerce is not unfrequently made the instrument of suicide or of murder. In such cases it often happens that the physician is called into a court of justice to give his evidence, and to state the facts upon which he has founded his judgment. It is therefore of the highest importance that he should be possessed of the knowledge requisite to detect the presence of arsenic, and to form an opinion from circumstances less equivocal than symptoms. This knowledge consists in the use of proper chemical tests, by which the compounds of arsenic may be recognized, even when they are found in minute quantities. The method of detecting arsenic when it has been taken into the stomach in a solid form is as follows.

1. From its irritating property, the arsenic will, in almost every case, be rejected with the other contents of the stomach;* these, if saved, are to be diluted with pure cold water if necessary, and allowed to remain for some time at rest. The arsenic, from its gravity and insolubility, will subside to the bottom of the vessel, and the liquid above may be carefully poured off. A white powder will be found, which is to be collected and dried. The liquid should likewise be filtered, and be preserved for examination; and particularly so in cases in which the solid is in minute quantity; or there has been reason to suppose the arsenic to have been given in solution.

If death have been produced, the abdomen is to be opened, a ligature should be put around the œsophagus, and a second around the duodenum, and the stomach, after being removed, should be opened in a basin of cold water, and its contents washed out.

If a white powder have, by these means, been procured, it must be submitted to the following examination.

2. Mix a little of it with an equal weight of black flux, or dry charcoal powder, put the mixture into a glass tube open

* I have said in almost every case, because in one instance no vomiting occurred, though the person took a sufficient quantity to produce death; a paper containing a few grains of arsenic was found at the bed-side.

only at one end, 3 or 4 inches in length, and 2 or 3 lines in diameter, close the mouth with a piece of paper or clay, and heat the part which contains the mixture for 10 or 15 minutes in the flame of a lamp. When cooled, its internal surface, if the mixture contained arsenic, will be found covered with a film of a bluish colour, slightly iridescent, and of a metallic lustre.

3. Boil a grain or two of the powder with half its weight of pure potash, or carbonate of potash, in a small quantity of distilled water contained in a glass vessel, until a solution of both be formed. When cold, add a few drops of the solution to a solution of 5 grains of *blue vitriol*, (sulphate of copper) in one ounce of water; if arsenic be present, a beautiful *grass-green* precipitate will immediately take place.

4. Dissolve a few grains of lunar caustic in boiling water, and filter the solution. Dip the end of a glass rod in the alkaline solution mentioned above, and bring it in contact with the surface of the solution of silver, a *dense yellow precipitate* will immediately take place. If the arsenic be dissolved in water, it will be necessary previously to dip one end of the rod in liquid ammonia, and apply it to the solution of lunar caustic, before the drop of arsenical solution is brought into contact.

The same kind of precipitate may be formed by touching a solution of arsenite of potash, or soda, with the end of a cylinder of lunar caustic.

5. The yellow coloured precipitate is arsenite of silver. But it has been found that the alkaline phosphates, and even phosphoric acid alone, when ammonia is present, will produce in solution of nitrate of silver a yellow deposit. Hence this test is liable to uncertainty, unless some further examination be made.

According to Dr. Marcet, the *arsenite* of silver grows brown on exposure to light; when recently made, it is soluble in nitric acid, and in excess of ammonia; it is decomposed by heat, and when the process is conducted in a tube, a white

vapour ascends, which condenses in minute octoedral crystals. The *phosphate* of silver, on the contrary, when thus exposed to heat, yields no smoke, nor crystalline sublimate ; and when urged on charcoal before the blow-pipe, forms a vitreous, greenish coloured, and difficultly fusible globule.*

After the use, therefore, of nitrate of silver, the yellow coloured substance should be dried, and then exposed to heat as above-mentioned. If it be arsenite of silver, the surface of the tube will exhibit arsenious acid, in the form of a white, crystalline, and granular sublimate. This, if united with potash, and added to a solution of blue vitriol, will give a grass green precipitate.†

If a considerable quantity of the yellow substance be obtained, one half may be used in the above experiment ; while the other half may be mixed with charcoal and exposed to a red heat in a closed glass tube. The oxide of arsenic will be reduced, and the metal will cover the surface in the form of a film of a bluish colour.

These are the tests most to be relied upon in the detection of arsenic ; but if the powder be not expended, the opinion respecting its nature may be confirmed by the following experiments.

6. Dissolve some of the powder by the aid of heat in muriatic acid, and add to the solution a recently made solution of sulphuretted hydrogen in water ; if arsenic be present, a straw yellow precipitate will be formed, which, before the blow-pipe, is entirely dissipated in fumes, and gives out an odour both sulphureous and alliaceous. This substance in fact is orpiment.

7. Mix a portion of the powder with charcoal and heat the mixture in the flame of a lamp, fumes will rise which have the odour of garlic. Dr. Paris affirms, that this odour is characteristic only of metallic arsenic, and that the vapour of its oxide is destitute of smell.

* Medico-Chirurgical Transactions, vol. vi. p. 663.

† Nicholson's Journal, vol. xxxiv. p. 174.

8. Mix some of the powder with charcoal and a little oil, put the mixture between two plates of polished copper, secure them with iron wire, and expose them to a red heat for 10 minutes. On separating the plates, and cleaning them with chalk, a white and permanent spot will be evident. The arsenic is reduced, and combines with the copper, forming an alloy.

9. Convert the arsenious into arsénic acid, dissolve it in water, and add it to solution of nitrate of silver, containing a little liquid ammonia, a red precipitate of *arsenate* of silver will be produced.

The nitrate of silver was applied as a test of arsenic by Mr. Hume, and the process has been improved by Dr. Marcet and Dr. Paris. It was objected to by Mr. Sylvester, from the circumstance, that if muriatic acid or its compounds were present, the precipitate must be white; he proposed, therefore, to substitute for it the *red acetate of iron*, which will produce with arsenic a bright yellow precipitate.* This objection, however, has been obviated by Dr. Marcet.† “To the suspected fluid, previously filtered, add, first, a little diluted nitric acid, and afterwards nitrate of silver, till it shall cease to produce a precipitate. The muriatic acid, being thus removed, while the arsenious acid (if any, and in whatever state) remains in the liquid, the addition of ammonia will instantly produce the yellow precipitate in its characteristic form. It is hardly necessary to add, that the quantity of ammonia must be sufficient to saturate any excess of nitric acid which the solution may contain.”

The precipitate from solution of blue vitriol is *arsenite* of copper. It is known in the arts by the name of *Scheele's green*.

* Nicholson's Journal, vol. xxxiii. p. 306.

† Ibid. Ibid. vol. xxxiv. p. 177.

SECTION II.

Of Molybdenum.

DXCVI. In 1778 Mr. Scheele obtained molybdic acid, and Hjelm reduced it to the metallic state in 1782. The metal may be obtained from the native sulphuret by acidifying both of its elements by nitric acid, and driving off the sulphuric acid by heat. The white powder which remains is to be mixed with oil, so as to form a paste, and then exposed, imbedded in charcoal, to the strongest heat of a forge. Another process, is repeatedly to roast the sulphuret in a red heat, to reduce it to a fine powder, and pass it through a seive. It is to be dissolved in ammonia, filtered, evaporated to dryness, and moderately heated. The residue is then to be treated as above mentioned.

Molybdenum is in the form of grains, or small masses, of a silvery white, but sometimes of a yellowish white, brittle, and of a specific gravity equal to 8.611. It is almost infusible. Exposed to heat and air, it becomes oxidized, and forms a white oxide which is volatile, and condenses in brilliant needle-shaped crystals.

Oxides of Molybdenum.

DXCVII. Molybdenum combines with two, and Bucholz affirms with three proportions of oxygen.

1. *Protoxide.* When molybdic acid is combined with ammonia and the solution is evaporated to dryness, if the dry mass be exposed to a white heat in contact with charcoal powder, it will be converted into a substance of a brown colour, of a crystallized appearance, and of a specific gravity equal to 5.6.

2. *Deutoxide or molybdous acid.* By triturating 1 part of powdered molybdenum with 2 parts of molybdic acid, in boiling water, and by evaporating the water at 120° Fah. there is formed a fine blue powder, which is molybdous acid. This

substance reddens vegetable blues, is soluble in water, and unites with salifiable bases, forming salts which are called *molybdites*.

3. *Tritoxide, or molybdic acid.* Formed by the action of nitric acid on molybdenum, it is in the shape of white scales, which, when melted and sublimed, become yellow ; it requires 960 parts of boiling water for its solution, and the solution changes vegetable colours. It is decomposed by being heated with charcoal, and also by some of the metals. It consists of about 100 of metal united with 50 of oxygen.

The molybdous acid is composed of 100 of metal + 34 of oxygen.

The protoxide most probably contains $\frac{1}{2}$ as much oxygen as molybdous acid. Hence, supposing them combined in definite proportions, their composition will be as follows.

Protoxide	-	-	-	100 + 16.6
Deutoxide	-	-	-	100 + 33.2
Tritoxide	-	-	-	100 + 49.8

The number for molybdenum will be 45 ; and the numbers for its oxides 52.5 ; 60 ; 67.5.

Molybdenum combines with sulphur and forms a sulphuret, which resembles the native sulphuret. It also unites with phosphorus.

Molybdic acid is soluble to a certain degree in sulphuric acid. The solution, which is made by the assistance of heat, is colourless, but changes to a blue as it cools. It is likewise dissolved by muriatic and nitro-muriatic acids ; but is insoluble in nitric acid.

Molybdic acid combines with the alkalies and forms salts called *molybdates*.

Molybdate of ammonia is incapable of crystallization ; when concentrated it is gelatinous ; it is decomposed by heat.

Molybdate of potash crystallizes in rhomboidal plates, shining, and of a metallic taste, soluble in water, and decompos-

able by ferro-cyanate of potash, which forms a precipitate of a reddish brown colour.

Molybdate of soda—crystals transparent—very soluble in water, neither efflorescent, deliquescent, nor volatile.

Molybdates of the metals are formed by adding an alkaline molybdate to solutions of metallic salts. The metallic molybdates are generally precipitated, and their colours vary with the metal with which the acid is united. A beautiful blue colour is formed with muriate of tin.

Molybdenum forms alloys with the other metals. The alloy with iron is of a bluish gray colour, brittle, of a granular texture, and difficultly fusible. Tin produces with molybdenum, a compound, soft, brittle, and of a dark gray colour. Molybdenum is applied to no use.

SECTION III.

Of Tungsten.

DXCVIII. Tungstic acid was discovered by Mr. Scheele, and its metal extracted by Mess. D'Elhuyars of Spain. It is found in a mineral called *Wolfram*, which, besides tungstic acid, contains iron, manganese, and tin. To procure this metal, finely powdered wolfram is to be boiled for some time in strong muriatic acid; when the solution is decanted there remains a yellow powder, which is to be washed, dissolved in ammonia, evaporated to dryness, and then exposed to the strongest possible heat for 20 minutes, mixed with finely powdered charcoal.

Tungsten, obtained in this way, is in small grains of a grayish white colour, of considerable lustre, brittle, very hard, and of a specific gravity amounting to 17.4. It is one of the heaviest of the metals. The metal obtained by the action of Mr. Children's great voltaic battery, presented characters almost precisely similar to those just mentioned.

As it is one of the heaviest, so it is also one of the most infusible of the metals, it being but imperfectly melted in the

processes employed for the reduction of its oxide. Its fusing point has been estimated at 170° of Wedgewood ; or about 2000° higher than the temperature of melting iron.

Oxides of Tungsten.

DXCIX. 1. Protoxide. This was obtained by Berzelius, by passing a current of sulphuretted hydrogen over the peroxide, and heating the product in a platina crucible. It is a puce coloured substance, soluble neither in acids, nor alkalis, but highly inflammable, taking fire before it is heated red hot, and changing to the peroxide. It consists, according to this chemist's experiments, of 100 of metal, with 16.5 of oxygen.

2. Peroxide. This oxide, when pure, possesses no acid properties. The *tungstic acid* of Scheele was found by Mess. D'Elhuyars to be a triple compound of this oxide, potash, and the acid employed in obtaining it from its ore ; and this conclusion has been confirmed by Vauquelin, and Hecht.

It is of a yellow colour, destitute of taste, and odour, insoluble in water, and incapable of affecting vegetable colours. It is partially decomposed by heat, and assumes a greenish colour ; before the blow-pipe it becomes black. According to the experiments of Berzelius, it consists of 100 metal and 24.12 of oxygen. From these analyses it appears that the protoxide contains very nearly $\frac{2}{3}$ as much oxygen as the peroxide ; if we consider them as existing in definite proportions, the protoxide will consist of

	Prop.					
Tungsten	1	-	-	100	-	-
Oxygen	-	2	-	16.6	-	-
	<hr/>					
	3					
	<hr/>					
						100.00

and the peroxide of

	Prop.						
Tungsten	-	1	-	-	100	-	80
Oxygen	-	3	-	-	25	-	20
		<hr/>					<hr/>
		4					100

So that, in calculating from the composition of the protoxide, the representative number of tungsten will be 90 ; that of the protoxide 105, and that of the peroxide 112.5.

Chloride of tungsten. This metal, according to Sir H. Davy, when heated and introduced into chlorine, takes fire and burns with a deep red light, forming an orange coloured volatile substance, which affords the yellow oxide of tungsten, and muriatic acid, when treated with water.* Its composition has not been ascertained.

Tungsten combines with sulphur and forms a grayish black powder, which, by friction, acquires a fine metallic lustre. It consists, according to Berzelius, of 100 of tungsten, and 33.26 of sulphur.†

It unites with phosphorus, but the compound has not been examined.

Tungsten appears to be incapable of acting on the strongest acids. Its oxides are scarcely dissolved by them, and its salts are unknown.

It forms triple compounds with the alkalies and acids.

It has been found equally difficult, in consequence of the extreme infusibility of tungsten, to combine it with the other metals. Some such combinations, however, have been made, but they presented no interesting properties.

Tungsten is applied to no use in the arts.

SECTION IV.

Of Chromium.

DC. This interesting metal was discovered in 1797 by M. Vauquelin, while analysing the beautiful, crystallized red-

* Elements, p. 429.

† Annals of Philosophy, vol. iii. p. 245.

lead ore of Siberia, or what is now called chromate of lead. It is not extensively diffused. It is found combined in the form of an acid with oxide of iron, and this chromate exists in considerable quantities near Baltimore. The chrome also constitutes the colouring matter of the emerald and ruby; and M. Vauquelin found it in small proportion in common serpentine from Liguria.

Chromium is now obtained from chromate of iron by repeatedly calcining 2 parts with 1 part of nitre in a crucible, and treating the mass with water, which is to be decanted and the residue subjected to the action of muriatic acid. The acid solution is poured off, and these processes are continued, until the ore is decomposed. The aqueous solutions are saturated with nitric acid and crystallized. The salt is redissolved in water and mixed with a solution of nitrate of mercury as neutral as possible. A red precipitate is formed which consists of chromate of mercury, and this, when washed, is to be decomposed by heat in a stone-ware retort. The residue is oxide of chromium, which to be decomposed requires to be mixed with charcoal powder, and submitted to the most violent heat.

Chromium is of a grayish white colour, brittle, of a radiated appearance, and of a specific gravity equal to 5.9. It is fusible only in an intense heat, and then presents on cooling compact portions, and needles crossing each other in all directions.

When exposed to the flame of the blow-pipe it acquires a green crust, and gives to borax a fine emerald green colour.*

Oxides. Chromium combines with three proportions of oxygen.

1. Protoxide of chromium is of a green colour, soluble in acids, and capable of combining with water so as to form a hydrate. Berzelius states the singular fact that when exposed to heat, it becomes ignited or burns, and diminishes in

* Vauquelin. Nicholson's journal, 4to, vol. ii. page 443.

bulk, but gains nothing in weight, so that the only effect appears to be a more intimate union of its elements.*

2. *Deutoxide of chromium*, formed by decomposing nitrate of chromium at a red heat, has a deep brown colour; it is shining, is insoluble in acids, and nearly so in alkalies, and decomposable by muriatic acid, chlorine being evolved, and protoxide of chromium remaining.

3. *Peroxide, or chromic acid*, is of an orange red colour, with a sharp metallic taste. It is very soluble in water, and the solution yields crystals in the form of long prisms of a ruby-red colour. Paper moistened with the solution, and exposed to the sun for some days, assumes a green colour. Heated with muriatic acid it produces a brisk effervescence, much chlorine is disengaged, and the solution becomes of a fine green colour. Heated before the blow-pipe, it boils, and is converted into the protoxide. It combines with the salifiable bases, and forms salts, which are called *chromates*.

According to the analyses of Berzelius, the green oxide is composed of 100 of metal, and 42.37 of oxygen; and chromic acid of 100 + 84.74. It is most probable that chromic acid contains 4 proportions of oxygen, and that the green oxide is a deutoxide; so that if all the oxides of this metal were known, the ratio of the oxygen to 100 of the metal, would be 21, 42, 63, 84.

Chromium acts very slightly upon the acids, and its oxide is dissolved by them with great difficulty. Its sulphate is decomposable by heat. The solution of the phosphate has a fine emerald green colour, while that of the oxalate is amethystine. The green oxide unites with the alkalies and forms green solutions, which are decomposed on being boiled.

Chromates.

DCI. Chromic acid, according to Vauquelin, may be obtained by adding the solutions of nitrate of barytes and chro-

* Annals of Philosophy, vol. iii. p. 105.

mate of potash to each other, dissolving the chromate of barytes in nitric acid, decomposing the solution by sulphuric acid, which precipitates the barytes, and then evaporating the solution to dryness.

Chromate of potash—soluble—solution lemon yellow—crystals, when neutral, in the form of fine prisms or rhomboidal prisms, of a citron yellow colour ; the colour of the bi-chromate is orange red.

Chromate of soda crystallizes in 6-sided tables, transparent, of a dark yellow colour. Both of these salts are decomposed by heat, oxygen gas is given out, and a mass is left having a green colour. They are likewise decomposed by sulphuric acid, by some of the bases, and by different metallic solutions, producing very beautiful precipitates. With mercury the precipitate is cinnabar red ; with silver, carmine red ; with lead, orange yellow ; with hydrosulphuret of potash, olive green. Some of these have a good body and permanent colour, and have been used as rich pigments.

The chromate of lead, particularly, has been manufactured in considerable quantities in Philadelphia, the chromic acid being obtained from the chromate of iron of Maryland.

Chromate of lime is in silky plates of a yellowish brown colour, easily soluble. Chromate of barytes is a light, yellow, and insoluble powder, similar to that of strontian. The magnesian chromate has a fine topaz yellow colour, crystallizes in large transparent 6-sided prisms, soluble in water, and producing an orange coloured liquid. Chromate of potash precipitates from sulphate of iron a fawn coloured substance, which contains oxide of chromium. The chromate of iron has not been formed by art ; but it exists native. According to Godon, chromic acid combines with silica, and produces a compound of a rose colour, insoluble in water, unalterable by heat. The silica should be in very fine powder.*

The uses of chromium at present are very limited ; but it is probable that from the beauty of its metallic combinations, it may, ere long, be extensively employed in the arts.

* Annales de Chimie, t. lii. p. 224.

SECTION V.

Of Columbium or Tantalum.

DCII. This metal was discovered in 1801, by Mr. Hatchet, in the mineral called Columbite ; and soon afterwards by Ekeberg in tantalite, and yttro-tantalite. The former called it Columbium, the latter, Tantalum. They were thought to be different substances until 1809, when Dr. Wollaston demonstrated their identity.

Columbium may be obtained from its ore by fusing 1 part of it with 5 of carbonate of potash, and 2 of borax, in a platina crucible, and digesting the resulting mass in muriatic acid. The oxides of the metals with which the columbium is associated, will be dissolved, while the latter will be left in the form of oxide. This oxide was reduced by Berzelius by putting it into a charcoal crucible, and exposing it to an intense heat.

Columbium or tantalum, thus obtained, was in the form of grains, imperfectly agglutinated, of a deep gray colour, and after friction exhibiting a metallic lustre, resembling that of iron. It is brittle, and when reduced to powder, it assumes a dark brown colour, destitute of brilliancy. Its hardness is such as to scratch glass. Its fusing point is at least as high as that of manganese. When heated, in contact with the air, to the temperature of ignition, it burns feebly and without flame, and acquires a grayish white colour. It is not acted upon by nitric, muriatic, nor nitro-muriatic acid: Deflagrated with nitre, it is converted into a fine white substance, which is a compound of the oxide with potash. By the use of muriatic acid, the potash may be removed, and the residue is oxide of columbium, consisting, according to Berzelius, of 100 of metal, and 5.485 of oxygen. The oxide is in this state combined with water, or the elements of water, in the proportion of 100 of the former to 12.5 of the latter.

In the state of hydrate it reddens delicate vegetable blues, is soluble in some of the vegetable acids, but insoluble in ni-

tric, and sulphuric acids. Muriatic acid takes up a very small proportion. It combines with potash by fusion in the proportion of 1 to 8, and forms a compound, soluble in water, and decomposable by muriatic acid, the oxide being precipitated in the form of hydrate. When heated in a retort the water is disengaged, and the compound no longer possesses the power of reddening blues. The hydrate evidently has acid properties, and has therefore been called *Columbic acid*; but they are lost when the water is expelled; a fact which Dr. Murray considers as an excellent illustration of the doctrine he has advanced, that in acids it is not water, but the elements of water, combined with the radical, and conferring upon it acid powers, by the joint influence of the oxygen and hydrogen.*

Columbic acid is of very difficult decomposition; and when submitted to the action of Mr. Children's voltaic battery, a small proportion only was fused into brittle grains, of a reddish yellow colour.

This acid combines more easily with potash than with the other alkalies. The combination may be effected by exposing them in the solid form to heat; or by boiling it in a solution of potash; a salt is thus formed which crystallizes in plates or scales resembling boracic acid. It has an acrid, disagreeable taste, is unalterable in the air, sparingly soluble in water, and decomposed by the acids, columbic acid being precipitated in the form of a white powder.

When infusion of galls is poured into the solution of this salt, an orange yellow precipitate is produced. It forms the same compound when added to the moist hydrate. Hence this infusion may be considered as the test of columbic acid.

The alloys of columbium and the other metals have not been particularly examined.

It is applied to no use.

* System of Chemistry, vol. iii. p. 509, 4th ed.

SECTION VI.

Of Selenium.

DCIII. The exact nature of this interesting and extraordinary substance can hardly be said to be defined. Its claims to be considered as metallic are somewhat doubtful, but it is described as such by Berzelius, and classed by him with the acidifiable metals, near arsenic.

In a manufacture of sulphuric acid in Sweden, belonging to Mess. Berzelius and Gahn, the sulphur employed is obtained from the copper mines of Fahlun, and when burned in the leaden chamber, it deposits a reddish mass, which for the most part consists of sulphur. From the odour given out during the combustion of this substance it was conjectured to contain tellurium, but on examination none of that metal could be detected. This circumstance led Berzelius to analyze it with greater care, and the analysis terminated in the discovery of a new metal, which, from its analogy to tellurium, he called *Selenium*. It appears to have been discovered about the commencement of the year 1818.

Selenium has a gray colour, a vitreous fracture, and a metallic lustre. It is hard, but like sulphur brittle, and when reduced to powder has a red colour, with a slight metallic lustre. Its specific gravity is 4.6.

At the temperature of boiling water it softens ; in a higher heat it melts, and may be distilled in close vessels at the temperature of boiling mercury. Its gas or vapour is exactly like that of sulphur ; and when the sublimation is effected in a large receiver, it condenses in the form of flowers of a cinabar-red colour. During its cooling, it preserves a certain degree of ductility, so that it may be moulded between the fingers, and drawn into threads of great fineness, which, by transmitted light, are of a ruby colour, by reflected light, are opaque, brilliant, and metallic. If sublimed in the air without taking fire, it evaporates in the form a red vapour, desti-

tute of odour. But when heated in the flame of a candle, or by the blow-pipe, it tinges the flame blue ; and, at the same time exhales so powerful an odour of horse-radish, that if $\frac{1}{30}$ of a grain be evaporated, it is sufficient to fill the air of a large apartment. Klaproth stated, that tellurium gave out the same odour ; Berzelius could not obtain it from the metal itself, its oxides, or its alloys, by heating them in the usual way, but by volatilizing tellurium in a small glass globe, before the flame of the blow-pipe, and permitting the escape of the vapour through a small orifice, the odour was precisely the same as that of selenium.

Selenium dissolves in nitric acid by the aid of heat ; the solution, evaporated and sublimed, yields a mass of needle-form crystals, acid to the taste, and capable of forming specific salts with different bases.

This crystallized substance has all the properties of an acid, and was therefore called by Berzelius *Selenic acid*. It is soluble in water and alcohol. The alkaline seleniates crystallize with difficulty, and are deliquescent. Seleniate of ammonia is decomposed by heat, water and azote are given out, and the selenium is reduced. Seleniate of barytes is soluble in water, but scarcely soluble in alcohol. It crystallizes in needles, which gradually accumulate in such a way as to form globular crystals, in which the fibrous structure cannot be detected even by the microscope.

Selenium combines with the alkalies both in the dry and humid way, forming compounds which are red, and are called *selenurets* ; those of the alkaline earths have the same colour, but are insoluble in water. There exist also selenuretted hydro-selenurets of the alkalies, and earths.

Hydro selenuret of potash becomes covered with a red pellicle, which, as it increases, changes to a grayish substance. It is decomposed by muriatic acid, and a red precipitate takes place.

Selenium combines with the metals, and the combination is generally accompanied with flame. Selenuret of potas-

sium has the metallic lustre, and a grayish white colour. It dissolves in water without effervescence and produces a fluid of a red colour, which has the taste of hydro-sulphuret of potash. If muriatic acid be poured upon this selenuret, selenuretted hydrogen gas is disengaged, which is soluble in water, and precipitates all metallic solutions, even those of zinc and iron. The gas has the odour of sulphuretted hydrogen, when it is diluted with air ; but if it be breathed less diluted, it produces a powerful sensation in the nose, and a violent inflammation, ending in a catarrh, which lasts for some time. Berzelius suffered severely from breathing a bubble of this gas no larger than a pea.

Selenic acid is decomposed by zinc. If muriatic acid be added to solution of a seleniate, and a plate of zinc be added, selenium is precipitated in red flocculi. If the experiment be performed with sulphuric acid, sulphuret of selenium of a gray colour is formed. Sulphuretted hydrogen, passed through an aqueous solution of selenic acid, produces a precipitate of an orange colour, which changes to a red on drying ; and which, when heated, melts, sublimes, and forms a transparent mass of an orange colour.

Selenium is a non-conductor of electricity and caloric.

Such are the properties of selenium, so far as they have been made known through the medium of the philosophical journals.* It obviously bears a great resemblance in many properties to sulphur, and in some to tellurium. Its specific gravity and its metallic lustre, are circumstances which favour the opinion of its being a metal.

SECTION VII.

Of Antimony.

DCIV. There is kept in the shops for medicinal purposes, a substance of a bluish colour, metallic brilliancy, of considerable specific gravity, and crystallized in needles, which

* *Annals of Philosophy*, vol. xi. and xii.

cross each other in various directions. It is a compound of sulphur with antimony. If the powder of this substance be added to iron filings heated to ignition in a crucible, its sulphur will be attracted by the iron, and the antimony in its metallic state may be run into a mould. Or it may be obtained by roasting the sulphuret, mixing the residue with black flux, or crude tartar, and exposing the mixture to a red heat.

Antimony is of a bluish white colour, brilliant, of a foliated texture, of a degree of hardness equal to that of zinc, brittle, and easily reduced to powder. Its specific gravity is about 6.7.

At the temperature of 810° , it melts, and in cooling, may, by cautious management, be obtained crystallized in tetrahedra. Its internal structure is crystalline, and it appears to be composed of rhomboidal plates, intersecting each other. Antimony may be sublimed, unaltered, in a very high heat.

Antimony suffers little alteration on exposure to the air, or to water, but at the temperature of ignition, it is said, by Lavoisier and Meusnier, to decompose the vapour of water so rapidly as to produce explosions. It should, perhaps, from this property, have been placed in the preceding division, but it is described here because, by many chemists, it is considered as an acidifiable metal.

Antimony with Oxygen.

DCV. Antimony combines readily with oxygen, but great difficulty has been experienced in determining the number of its oxides. Mr. Proust reduced them to 2;* M. Thenard enumerated 6,† but now describes but 3;‡ Bucholz procured 2, and Berzelius 4;§ while by M. Gay-Lussac, there are thought to be but 3 oxides.¶ The protoxide of Berzelius is

* Journal de Physique, lv. p. 325.

† Annales de Chimie, t. xxxii. p. 259.

‡ Traité de Chimie, t. ii. p. 89, 2de ed.

§ Annals of Philosophy, vol. iii. p. 248.

¶ Annales de Chimie et de Physique, t. v. p. 162.

considered by some able chemists, as a mixture of metallic antimony with the deutoxide. Hence there appears to be but three well defined compounds of this metal with oxygen.

1. *Protoxide*. It may be formed by calcining antimony at a red heat, in contact with the air, in an apparatus which will allow of the collection and condensation of vapour. The metal becomes oxidized, and rises in the form of a white smoke, which condenses in crystals or in powder. This oxide has been known in medicine by the name of *argentine flowers of antimony*. The same compound may be obtained by a process somewhat complicated from chloride of antimony. It is then grayish white, but its composition, according to Thenard, is precisely the same as that of the oxide procured by the other method.

The protoxide is white, with a shade of gray, fusible at a red heat, and on cooling forms a crystalline mass, resembling asbestos. It may be sublimed by heat, and its vapour while condensing frequently forms crystals. It consists, according to Berzelius, of 100 of metal and 18.60 of oxygen, and this analysis corresponds, within a few fractions, with that of M. Thenard, who estimates the oxygen at 18.50. Its composition may be stated to be as follows.

	Prop.					
Antimony	-	1	-	-	100	- - 84.34
Oxygen	-	1	-	-	18.60	- - 15.66
		<hr/>				<hr/>
		2				100.00

So that the representative number of antimony will be 40.3, and that of its oxide 47.8.

2. *Deutoxide, or antimonious acid*. It may be obtained by heating the protoxide in the air nearly to redness, it takes fire, and absorbs oxygen. It may likewise be formed by evaporating to dryness the nitric solution of antimony and heating the mass to redness. It is white, insoluble in water, unalterable in the air, fusible at a high heat. When melted

with $\frac{1}{4}$ part of antimony, the whole is converted into protoxide. It combines with salifiable bases and forms salts. Hence it has been considered as an acid, and by Berzelius called *Stibious acid*, from *Stibium*, one of the old names of antimony. Other chemists prefer the term *antimonious*. According to Berzelius, it contains 24.8 of oxygen; according to Thenard, 27.07 of oxygen, united with 100 of metal.

3. *Tritoxide, or antimonie acid*. Obtained by mixing powdered antimony with 6 times its weight of nitre, and exposing the mass for an hour to a red heat. The product is dissolved in water, and decomposed by an acid; antimonie acid separates, which is to be collected and dried. It is procured likewise by decomposing red oxide of mercury by antimony. It is a yellow powder, insoluble in water, but capable of reddening vegetable blues. But, according to Dr. Murray, it has this effect only when in the state of hydrate. It is apparently incapable of combining with acids. Exposed to heat, it gives off oxygen and is changed to deutoxide. It consists, according to the analysis of Berzelius, of 100 of antimony, and 37.2 of oxygen.

Chloride of Antimony.

DCVI. When powdered antimony is projected into chlorine, the metal burns with a brilliant white light, and dense white fumes are formed, which are highly acrid and corrosive. If the gas be dry, the result is a chloride; if the vessel contain water, a white powdery substance will be seen at the bottom, and the odour of muriatic acid will be perceptible.

Chloride of antimony is usually formed by distilling 1 part of antimony with 2 of corrosive sublimate, a substance sublimes which was formerly familiarly known by the name of Butter of antimony.

The pharmacopœias give processes differing from the above; it may likewise be formed by the action of nitro-muri-

atic acid on antimony, and M. Robiquet has given directions by which a pure and beautiful chloride may be produced.*

Its appearance is that of a fatty mass, of a grayish white colour, often crystallized in 4-sided prisms. It is acrid and corrosive, and was formerly used as a caustic. Exposed to the air it deliquesces, and to heat sublimes. By the affusion of water it is decomposed, muriatic acid is formed, and a white oxide is precipitated, which, among the older chemists and physicians, was known by the name of *powder of algaroth*. Dr. J. Davy found this chloride to consist of 60.42 of antimony, and 39.58 of chlorine. If the number we have assigned for antimony be correct, its composition from calculation will be as follows.

		Prop.					
Antimony	-	1	-	100	-	-	54.60
Chlorine	-	1	-	83.15	-	-	45.40
		<hr/>					<hr/>
		2					100.00

And its number will be $33.5 + 40.3 = 73.8$.

Antimony combines with iodine, and forms a compound of a dark red colour, which, by digestion in water, is converted into hydriodic acid, and oxide of antimony.

Phosphuret of Antimony.

DCVII. This compound, formed in the same way as the other metallic phosphurets, is white, brittle, of a lamellated structure and decomposable by heat, burning with a green flame, and oxide of antimony subliming.

Sulphuret of Antimony.

DCVIII. Sulphuret of antimony may be prepared by exposing a mixture of its elements to heat. This sulphuret exists abundantly in nature, and the older chemists designated it by the name of antimony. When the metal was obtain-

‡ Annals of Philosophy, vol. xii. p. 21.

ed from it, they called the metal itself *Regulus of antimony*. It is of a lead-blue colour, of a metallic brilliancy, and of a radiated or foliated texture. Dr. Thomson's analysis of this sulphuret gives, as its constituent parts, 100 of metal with 35.572 of sulphur; Berzelius assigns 100 of antimony to 37 of sulphur. It consists of 1 proportion of each of its elements, and may be represented by $40.3 + 15 = 55.3$.

When this sulphuret is exposed to heat and air, a portion of sulphur is driven off, the metal, or a portion of it, becomes oxidized, and if strongly heated, it is converted into a dark coloured yellow glass. It is the *vitrum antimonii* of the physicians. It is inferred to be a compound of oxide of antimony with a small proportion of sulphur and silica, the last of which proceeds from the crucible.

The saffron of antimony, the *crocus metallorum* of the old dispensatories, is prepared by deflagrating equal weights of the sulphuret and nitre. Its composition is not exactly known. Proust considers it as a compound of oxide of antimony and sulphuret of antimony.

Diaphoretic antimony is a combination of peroxide of antimony, or an-imoniac acid with potash. It is prepared by deflagrating sulphuret of antimony with 3 times its weight of nitre, washing the residue with water and drying it.

Kermes mineral, a medicine so famous at one period, is apparently a hydro-sulphuretted oxide of antimony, prepared by boiling the sulphate in solution of potash or carbonate of potash, oxide of antimony and sulphuretted hydrogen are formed, together with hydro-sulphuret of potash. The solution is transparent while hot, but as it cools the kermes precipitates in the form of a brick red powder. If, before its deposition, diluted sulphuric acid be added to the solution, sulphur and hydro-sulphuretted oxide of antimony are precipitated in intimate mixture and in minute division. This powder constitutes the old *Sulphur auratum antimonii*, golden sulphur of antimony; the *sulphuretum antimonii præcipitatum* of modern pharmacopœias. Thenard found the kermes to be composed of 72.76 of oxide of antimony, 20.298 of

sulphuretted hydrogen, and 4.156 of sulphur ; the golden sulphur of 68.3 of yellow oxide, 17.877 of sulphuretted hydrogen, and 12 of sulphur.*

Antimony with Acids.

DCIX. Nitric acid is decomposed by metallic antimony, and peroxide of antimony formed, which is insoluble in the acid and precipitates in the form of a yellowish white powder.

Muriatic acid acts but feebly on antimony ; hydrogen gas is given off. The compound has been already described under the head of chloride of antimony.

Antimony when boiled with sulphuric acid decomposes it, sulphurous acid passes off, the metal becomes oxidized and forms a sulphate with the remaining acid. It is decomposed by water into two salts, a sulphate and bi-sulphate, the former remains in solution, the latter precipitates.

Nitro-muriatic acid acts readily upon this metal.

Antimonic acid with bases.

DCX. *Antimoniate of potash*, formed by deflagrating antimony with 6 parts of nitre, washing the product with water and drying it, is white, has an acrid, somewhat metallic taste, is soluble in boiling water, and the solution on cooling is permanent. Exposed to heat until the water is evaporated, it forms a substance like enamel. If the evaporation be suspended when the solution has acquired the consistence of syrup, it deposits a powder, light and granulated. To decompose this salt, it requires to be repeatedly digested with nitric acid. It consists, according to Berzelius, of 20.8 parts of potash, and 79.2 of antimonic acid.

Antimoniate of ammonia is formed by digesting antimonic acid in the state of hydrate in caustic ammonia ; it is decomposed by a moderate heat. Antimoniates of barytes, lime, iron, and zinc may likewise be produced by the addition of antimoniate of potash to the solutions of their respective salts.

* *Annales de Chimie*, vol. xxxii, p. 268.

The combinations of the deutoxide, or the antimonious acid with bases are not very extensive, and they have been but little examined.

The oxides of antimony form likewise ternary compounds, some of which are extensively employed in medicine. The tartrate of antimony and potash is the most important, and though the properties of tartaric acid have not been described, it may with great propriety be introduced in this place.

Tartrate of potash and antimony. Tartar Emetic. This celebrated medicine is prepared by a variety of processes, the object of which is to combine protoxide of antimony with the super-tartrate of potash. *Cream of tartar* is properly a bi-tartrate of potash, or that base combined with a peculiar vegetable acid, called the Tartaric in excess. The oxide combines apparently with this excess, and forms a peculiar triple salt. The different methods of preparing tartar emetic may be found in the works quoted in the margin.*

The formula of the Massachusetts pharmacopœia, which is taken from that of the Edinburgh college, is to boil 3 parts of sulphuretted oxide of antimony with 4 parts of super, or bi-tartrate of potash, in 32 parts of distilled water, for a quarter of an hour, filtering the liquid, and setting it aside to crystallize. According to Thenard there is always a quantity of uncombined cream of tartar in the solution, and if it be evaporated far, a portion of it will be deposited.

Tartar emetic is in the form of triedral pyramids, transparent, and efflorescent in the air. It is soluble in about 15 parts of cold water, and much less of boiling water. It is decomposed by heat, carbonate of potash and oxide of antimony remaining. When its solution in water is allowed to remain at rest for a little time, the salt gradually undergoes decomposition, and the same effect takes place in its vinous solution. Hence, for medicinal purposes, they should be employed in their recent state. The decomposition of this

* Experimental Examination of the Pharmacopœia Londinensis, by Mr. Phillips. Powell's London Pharmacopœia.

salt is immediately effected by the alkalies, alkaline earths, and some of the metals. Vegetable infusions or tinctures which contain tartaric or gallic acid, destroy the compound. According to Thenard the tartrate of potash and antimony consists of 38 of oxide of antimony, 16 of potash, 34 of tartaric acid, and 8 of water. Dr. Thomson infers that it is composed of acid 46.53, oxide of antimony 36.81, potash 16.66.

Phosphate of antimony and lime. James' powder. The nature of this celebrated antimonial powder was first ascertained by Dr. Pearson of London.* He found it to be composed of 43 parts of phosphate of lime, and 57 of oxide of antimony, 28 parts in 100 of which were vitrefied. It is prepared, according to the London pharmacopœia, by calcining 1 part of sulphuret of antimony, and 2 parts of shavings of hartshorn in a broad iron pot, heated to whiteness until the mass acquires a gray colour. It is then to be reduced to powder and subjected to a white heat for two hours in a crucible, to which has been luted a second, having a small hole in its bottom. When reduced to a very fine powder, it constitutes the *pulvis antimonialis*, or *oxidum antimonii cum phosphate calcis* of the pharmacopœias. It is not yet decided whether it be a mixture of phosphate of lime and oxide of antimony, or phosphates of both; or a triple compound of phosphoric acid, lime, and oxide of antimony.

The salts of antimony are precipitated of an orange yellow by hydrosulphuret of potash. They are also decomposed by metallic iron and zinc, a brown or black powder being precipitated.

Alloys of Antimony.

DCXI. Antimony combines with potassium with the evolution of light and heat. The alloy is in fine grains, of a lustre nearly equal to that of tin, brittle, fusible, and caustic.

* Philosophical Transactions for 1791, p. 317.

It is decomposed on exposure to the air, and effervesces violently with water.* Its alloy with sodium is similar in properties.

Antimony may be combined with iron, forming what was once called martial regulus of antimony, by melting together 2 parts of its sulphuret and 1 of iron. It is white, hard, brittle, and of a specific gravity less than the mean of the two metals.

Zinc forms with antimony an alloy hard and brittle. With tin it constitutes a compound which is ductile and malleable, and which consists of 1 part of antimony to 4 of tin. Thenard observed, that when water was added to a solution of this alloy in muriatic acid, the solution was decomposed and the whole of both metals precipitated.

Uses of Antimony.

DCXII. Antimony is employed with lead in the formation of printers' types, and with tin in the fabrication of plates on which music is engraved. It also enters into the composition of pewter. Its oxides impart a hyacinthine colour to glass, and are used in the composition of pastes and enamels. It is one of the most important articles of the *Materia Medica*.

SECTION VIII.

Of Tellurium.

DCXIII. Tellurium was discovered in 1798 by Klaproth. It is found in nature only in small quantities, and is obtained from an ore of Transylvania, in which it is alloyed with gold, silver, and lead.

Tellurium has a colour intermediate between that of tin and antimony; its lustre is metallic; it is brittle, of a foliated structure, and of a specific gravity equal to 6.115. Exposed to heat it melts readily and is volatile, rising in vapour

* Gay-Lussac and Thenard. *Rechères*, p. 219.

at a temperature near to ignition, and in that state, as was proved by Berzelius, gives out a strong odour of horse-radish. This vapour in close vessels condenses in brilliant metallic globules. When melted and slowly cooled its surface presents a crystallized appearance.

Tellurium with Oxygen.

DCXIV. When tellurium is heated before the blow-pipe, it takes fire and burns with a brilliant light, of a greenish blue colour, and grayish white vapours are formed, which speedily condense into a white solid. This oxide of tellurium heated in a close vessel melts, and on cooling is converted into a mass of a yellow colour and striated texture. It is volatilized in a very high heat, and is capable of uniting with water so as to form a hydrate. According to Klaproth, it consists of 100 of metal and 20 of oxygen. Berzelius states them to be in the proportion of 100 to 24.4, or 24.8. If we take the mean of the numbers for oxygen, and consider it as 22.4, and the oxide as containing 1 proportion of each, its composition may be stated as follows.

	Prop.						
Tellurium	-	1	-	-	100	-	81.70
Oxygen	-	1	-	-	22.4	-	18.30
		<hr/>					<hr/>
		2					100.00

Hence the representative number of Tellurium is 33.4, and that of its oxide 40.9.

The oxide of tellurium has been considered as an acid, and been called *telluric acid*, but its claims to this term do not appear to be well supported.

Tellurium with Chlorine.

DCXV. Introduced into chlorine, tellurium burns spontaneously and forms a chloride which is volatilized at a moder-

ate heat and crystallizes as it condenses. It is white, semi-transparent, and decomposable by water, hydrated oxide of tellurium being precipitated. According to Sir H. Davy, it consists of 2 in weight of metal united with 1.83 of chlorine. It may be considered as composed of 1 proportion each of its elements.

Tellurium combines apparently in 2 proportions with hydrogen, one compound being solid, the other gaseous.

It was observed by Ritter that when tellurium was negatively electrified in contact with water, by the voltaic apparatus, a brown substance was produced, which he conceived to be a solid compound of the metal with hydrogen. The same result was obtained by Sir H. Davy. This *hydruret of tellurium* imparts a purple colour to the water, and after a while precipitates. If sulphuric or muriatic acid be present in the water, it is not precipitated, but becomes gaseous. It then constitutes

Telluretted Hydrogen.

DCXVI. It may be obtained for experiment by heating together at the temperature of ignition, potash, oxide of tellurium, and charcoal. When put into a retort connected with a mercurial apparatus, and acted upon by diluted sulphuric acid, this compound gives off the gas in question.

It is a permanently elastic, invisible fluid, of a peculiar, penetrating odour, not unlike the smell of sulphuretted hydrogen. When ignited, it burns with a blue flame, and deposits oxide of tellurium. It is soluble in water, to which it imparts a claret colour; it combines with the alkalies, and precipitates many metallic solutions. Chlorine gas decomposes it, muriatic acid being formed, and tellurium deposited.

This gas was discovered in 1809 by Sir H. Davy;* and it was subsequently examined by Berzelius.†

* Elements of Chemical Philosophy, p. 410.

† Nicholson's Journal, vol. xxxvi.

No accurate experiments have yet been made to determine the proportion of the elements in the hydruret, and in telluretted hydrogen.

Tellurium with Acids.

DCXVII. The principal acids are acted upon by this metal and peculiar salts are formed.

Nitrate of tellurium, obtained by evaporation from its transparent nitric solution, is in small white needle-form crystals, of a dendritic appearance.

Muriate of tellurium is transparent in solution, is decomposable by water, and deposits a white substance which is redissolved by the addition of more water. Precipitated by alcohol, and washed, the substance contains but little acid.

Sulphate of tellurium in solution is of a red colour, which becomes transparent, and deposits black flakes by the affusion of water. When exposed to heat, all colour disappears and white oxide of tellurium separates. If a little nitric acid be added to the sulphuric acid, a colourless solution is formed which is not affected by water.* Oxide of tellurium also combines with alkaline and metallic bases; the compounds have been examined only by Berzelius; and in consequence of the small quantity of tellurium which he possessed, his experiments were not very extensive.

Tellurium combines with sulphur, and forms a sulphuret of a leaden gray colour, a radiated texture, and which has the property of burning with a green flame.

This metal is precipitated in its metallic state by iron, zinc, tin, and antimony.

Tellurium combines with great energy with potassium, much heat and a vivid light are produced. The alloy has a crystalline texture, a dark colour, and is brittle. It is decomposed in the air, and in water; and when the latter contains sulphuric acid, telluretted hydrogen gas is disengaged.

* Berzelius. Nicholson's Journal, xxxvi. 130.

Tellurium is found only in very small quantities, and is applied to no useful purpose.

SECTION IX.

Of Cerium.

DCXVIII. Cerium was obtained by Mess. Hisinger and Berzelius from a mineral found in Sweden, and from the coincidence of its discovery with that of the planet Ceres, called Cerite. The fact of the existence of cerium was confirmed by Vauquelin.

This mineral is dissolved in nitro-muriatic acid. The solution is to be filtered, the acid saturated with potash, and tartrate of potash, or oxalate of potash added till the precipitation ceases. The solid substance, when collected, well washed, and dried, constitutes oxide of cerium.

The attempts which have been made to reduce this oxide have been almost uniformly unsuccessful. It is either volatile below the temperature necessary to separate its elements, or their affinity is so powerful, that it resists the attraction of carbonaceous and metallic matter for oxygen, when aided even by the most intense heat. Vauquelin obtained it in the form of a minute globule, alloyed with iron. The oxide of cerium was not decomposed by Mr. Children's voltaic battery; but it was melted, and when intensely heated, it burned with a large vivid white flame, and was partly evaporated. The fused oxide, on exposure to the air, fell to powder in a few hours. There is sufficient evidence that the radical of oxide of cerium is a peculiar metal. Cerium combines with 2 proportions of oxygen. When precipitated from its acid combinations it is white, but becomes yellow on drying. This is the *protoxide*, and it consists, according to Hisinger, of 100 of cerium, and 17.41 of oxygen. This would give the equivalent number of cerium as 43.

The peroxide of cerium is obtained by precipitation from some of its acid combinations; or by exposing the protoxide

to a long continued heat, by which it is converted into a red coloured substance, insoluble in water, and infusible. It is composed of 79.29 of metal and 20.71 of oxygen.

The globule of cerium obtained by Vauquelin, was acted upon by no acid but the nitro-muriatic. But its compounds with oxygen, particularly the protoxide, appear to enter into combinations with the acids with sufficient facility.

The *protonitrate of cerium*, when in solution, is colourless, has an acrid, yet sweetish taste, and crystallizes with difficulty.

The *per-nitrate*, formed by the aid of heat, crystallizes in small white crystals, soluble in water and alcohol, and deliquescent. Muriatic acid dissolves the protoxide and disengages chlorine. The solution has a slight greenish yellow colour, and by evaporation affords a crystalline mass, deliquescent, and soluble both in water and alcohol.

The carbonate and phosphate of cerium are white powders, insoluble in water.

Sulphate of cerium contains the peroxide. Its crystals are of a yellow colour, and of an octoedral form, or acicular, soluble in water with an excess of acid, and producing a solution with a sweetish taste. This salt is efflorescent.

These salts are decomposed by the alkalies.

Hydro-sulphuret of potash produces a white precipitate. Sulphuretted hydrogen occasions no change. Triple prussiate of potash throws down a white powder; and the same effect is produced by oxalate of ammonia. The solutions of cerium are not precipitated by iron or zinc.

SECTION X.

Of Cobalt.

DCXIX. Cobalt was discovered in 1752, by Brandt, a Swedish chemist. It may be obtained from the zaffre of commerce.

It is of a grayish white colour, with a slight tinge of red, of a fine granular texture, with some lustre, of considerable

hardness, and of a specific gravity equal, according to some chemists, to 7.7, and to others, to 8.7. It is brittle, and requires for its fusion a temperature nearly as high as the melting point of iron. It may, by cautious management, be obtained crystallized in irregular prisms. Cobalt is not only attracted by the magnet, but it is itself capable of acquiring the magnetic power by the same means which are practised with regard to iron. Chenevix denied that it possessed this property, and attributed it to the presence of iron, but the researches of Wenzel, and of Tassaert, have sufficiently demonstrated, that it is independent of that metal.

Cobalt combines with 2 proportions of oxygen. It suffers very little change even on long exposure to the air, but when heated for some time, it attracts oxygen, becomes covered with a blue powder, which colour increases in intensity until it appears nearly black. The same substance may be precipitated from nitrate of cobalt by potash. This is the *protoxide* of cobalt. It dissolves in muriatic acid, and produces a green solution, which changes to a red on being diluted with water.

When this protoxide is heated in contact with the air, it changes to a brown, and finally, to a black powder. It then constitutes *peroxide* of cobalt. If heated intensely, it gives off oxygen gas, and when treated with muriatic acid, evolves chlorine, and forms a red coloured solution. Few experiments have been made to ascertain the proportions of the elements in these two oxides, and the results of these are very discordant. According to Proust, the protoxide consists of 100 of metal, and 19.8 of oxygen; and the peroxide of $100 + 33.25$. Rothoff states the former at $100 + 27.3$, and the latter at $100 + 40.95$. Klaproth gives the proportions in the protoxide at $100 + 13$. If Klaproth's analysis be adopted, and the protoxide be considered as consisting of 1 proportion of each of its elements, then the number for cobalt will be 41.6.

Cobalt combines with chlorine; and the combination may be effected by introducing chlorine into an exhausted vessel

containing the metal in fine powder, and gently heating it. A combustion takes place, but the properties of the compound have not been examined.

Cobalt likewise unites with phosphorus and sulphur.

Phosphuret of cobalt is white, of a metallic lustre, and striated texture, brittle, and more fusible than cobalt.

Sulphuret of cobalt, which is formed with some difficulty, is of a yellowish colour and crystalline texture. It consists, according to Proust, of 100 of metal and 39 of sulphur. The sulphur probably exists in the proportion of 36 parts, in which case, it will conform to the law of combination announced by M. Gay-Lussac, that the oxygen in the protoxide of a metal is equal to one half the sulphur in the sulphuret.

Salts of Cobalt.

DCXX. The most interesting of the compounds of cobalt may be found in its acid combinations.

Nitrate of cobalt. Cobalt decomposes nitric acid, becomes oxidized, and then combines with the acid, forming a solution of a rose colour, which, when concentrated by heat, yields minute prismatic crystals, soluble in water, deliquescent, and decomposable by heat, the residue being a deep red powder.

Muriate of cobalt. Muriatic acid dissolves the oxide of cobalt with facility, and the compound may be formed by digesting zaffre in the liquid acid. The solution is blue, but when diluted with water to a certain degree, assumes a light pink colour. When evaporated, it produces acicular crystals which are deliquescent. It is decomposed by the alkalis, and if added in considerable excess, the oxide is redissolved. This is particularly the case when ammonia is employed, the protoxide being soluble in liquid ammonia.

The solution of muriate of cobalt is the best known and most celebrated of all the sympathetic inks. It is sometimes called Hellot's sympathetic ink, from the person who first

discovered its curious properties. It may be prepared by digesting zaffre for some hours in nitro-muriatic acid and diluting with water until the colour changes from a blue to a red ; or 1 part of zaffre with 4 of nitric acid, adding 1 part of common salt, and diluting with 4 of water. The solution then has a faint rose colour. Traces made with this solution on paper are invisible when dry at common temperatures, but if the paper be moderately heated, a beautiful bluish green colour will be developed. In the course of 15 or 20 minutes after being cooled the colour begins to fade, and in an hour or two they are again invisible. This experiment may be repeated for any number of times, provided the heat, to which the article has been exposed, have not been too high ; for, in that case, the traces remain permanent. Small articles, such as fire-screens, &c. may be managed, so as when cold to present the appearance of decayed vegetation, but when heated, to develop luxuriant foliage.

No satisfactory solution of this phenomenon has yet been offered. It has been supposed by some to depend upon a difference in the state of moisture in the salt in its different states ; and by others, upon the relative quantity of oxygen being altered as the temperature is varied. But with regard to the first explanation, it is shown to be erroneous by the fact that its solution experiences the same change on exposure to heat, even when enclosed in a phial ; and with regard to the last, it has been shown by M. Gay-Lussac, that the same change of colour takes place in circumstances in which the relative proportion of oxygen cannot be varied. It is possible that it may result merely from a difference in the state of aggregation in the particles of the compound.

A blue sympathetic ink may be formed by employing acetic acid or strong distilled vinegar, instead of muriatic acid, with the addition of common salt.

Sulphate of cobalt is of a red colour in solution, and may be obtained in acicular crystals, or minute rhomboidal prisms, which are faintly red, soluble in water, and permanent in the air.

From solutions of cobalt the alkalies throw down a blue precipitate. Ferruretted chyazic acid precipitates a brownish yellow substance, sometimes with a shade of blue. The precipitate by hydro-sulphuret of potash is black and soluble in an excess ; and that by infusion of galls is yellowish white.

Cobalt combines with many of the metals, but the alloys, thus formed, present no interesting properties, and are applied to no useful purposes.

Uses of Cobalt.

DCXXI. Oxide of cobalt is the substance which is employed to give to glass, enamel, and porcelain, a deep and beautiful blue colour. The power of the oxide in this respect is so great, that 1 grain will tinge half an ounce, or 240 grains of glass, of a fine blue. There are three forms of it known in commerce, viz. zaffre, smalt, and azure. When the ore of cobalt is smelted, the volatile metals are disengaged, and those which are fusible are melted out, the cobalt becomes oxidized, and is then mixed with the powder of flints and deposited in casks, in which it soon grows hard. It then constitutes zaffre. When this is fused, either alone, or with the materials of glass, it forms a deep blue vitreous compound, which, in the state of rather a coarse powder, is used in the arts by the name of smalt. Azure is smalt ground to an impalpable powder, and it is employed as a paint.

SECTION XI.

Of Titanium.

DCXXII. There is found in Cornwall, England, a black sand, which was called by Mr. Gregor Menachine, and which, when analyzed, was found by him to consist of oxides of iron, and of a new metal, that he could not reduce. Soon

afterwards Klaproth discovered the same oxide in the *red schorl*, and gave to the metal the name of Titanium. It has since been found in other minerals. The method of obtaining it consists in reducing the mineral to powder, and fusing it with potash ; on the affusion of water a portion only is dissolved, the remainder consisting of oxide of titanium in combination with potash. This is to be dissolved in muriatic acid, and decomposed by solution of oxalate of ammonia, a white and thick precipitate is formed, which, when washed and dried, is oxide of titanium.

This oxide is so refractory that no attempt to obtain the metal has been perfectly successful. According to Laugier, it is of a yellow colour, shining, brittle, and almost infusible. It tarnishes in the air, and deflagrates with fused nitre.

Exposed to heat and air it is converted into a blue powder, which is regarded as a *protoxide*. The *peroxide* is a native production ; it is red, and often crystallized in 4-sided prisms, of a specific gravity equal to 4.2, and so hard as to scratch glass. It is insoluble in sulphuric, nitric, muriatic, and nitro-muriatic acids ; but volatile in a very intense heat.

When this oxide is melted with thrice its weight of potash, and dissolved in water, a white powder precipitates, which has been considered as a peroxide. May it not be a hydrated red oxide ?

Titanium has not been combined with chlorine, nor with sulphur ; but it has been united with phosphorus, and a compound was formed of a pale white, of a metallic lustre, brittle, and of a granulated texture.

The oxides of titanium combine with the acids, and form salts, the properties of which are but imperfectly known. They afford white precipitates with the alkalies, and brownish red with tincture of galls. Some of the metals partially decompose the solutions and produce various colours ; zinc forms a violet and then an indigo blue, and tin a pale red, which soon changes to purple red. The peroxide of titanium gives to borax, when melted before the blow-pipe, the colour of the hyacinth.

The only known alloy of titanium is that with iron. It is of a gray colour, with brilliant yellow particles intermixed. It has not been melted.

The oxide of titanium has been used in manufactures of porcelain, to give to the articles a tint of brown.

SECTION XII.

Of Bismuth.

DCXXIII. Bismuth is white with a tinge of red, destitute, or nearly so, of taste and odour, of a lamellated structure, of a degree of hardness less than that of copper, and of a specific gravity equal to 9.822. It may with caution be flattened under the hammer, but not to any considerable extent; and when struck forcibly it falls to pieces. Its tenacity is such, that a rod, $\frac{1}{16}$ of an inch in diameter, will support a weight of 29 pounds.

Exposed to heat it melts at a temperature not higher than 486° Fah. and with care, may be obtained on cooling, in the form of brilliant cubes, or octoedrons. In a high heat, and in close vessels, it may be volatilized and condensed without alteration. If, at this temperature, it be exposed to the air, it takes fire and burns with a blue flame, producing vapours, which condense into a yellow coloured powder.

Bismuth with Oxygen.

DCXXIV. Exposed to heat and air, the surface of bismuth acquires a dark grayish pellicle, and by removing these pellicles as they appear, the whole of the metal may be thus oxidized. If it then be heated, and agitated in an open vessel, it is converted into a yellow powder. This powder constitutes the only known oxide of bismuth. It may be prepared according to the method of Lagerhjelm, by dissolving pure bismuth in diluted nitric acid, evaporating to dryness, and exposing the mass to a red heat.*

* Annals of Philosophy, vol. iv. p. 357.

Oxide of bismuth is yellow, insipid, inodorous, insoluble in water, and fusible by heat into a glass, transparent, and of a yellowish green colour. The different analyses of this oxide approach very nearly to each other. Dr. J. Davy states the proportions at 100 of metal + 11.11 of oxygen ;* Lagerhjelm at 100 + 11.28 ; and Dr. Thomson at 11.30. The mean of these numbers is 11.23. Hence it consists of

		Prop.					
Bismuth	-	1	-	-	100	-	90
Oxygen	-	1	-	-	11.23	-	10
		<hr/>					<hr/>
		2					100

The equivalent number of bismuth is therefore 66.7, and that of its oxide $66.7 + 7.5 = 74.2$.

Bismuth and Chlorine.

DCXXV. Bismuth, when thrown into chlorine, takes fire and burns with a pale blue flame, and the product is *chloride* of bismuth. It may likewise be formed by heating together a mixture of bismuth and corrosive sublimate, and keeping the mass in a melted state for some time ; the excess of bismuth subsides, and the chloride remains above in a pure state.

When the oxide of bismuth is acted upon by muriatic acid, a liquid is formed, which, if evaporated to dryness and distilled, yields the same compound.

Chloride of bismuth, formerly called butter of bismuth, is of a grayish white colour, opaque, of a soft consistence, of a somewhat granular texture, acrid, and corrosive. It is neither fusible, nor volatile. When water is poured upon it, oxide of bismuth is separated, and muriatic acid formed. It is composed, according to Dr. J. Davy, of 66.4 parts of bismuth, and 33.6 of chlorine. Its composition may be thus stated.

* Philosophical Transactions for 1812.

	Prop.						
Bismuth	-	1	-	-	100	-	66.4
Chlorine	-	1	-	-	50.60	-	33.6
<hr/>							<hr/>
		2					100.0

And its equivalent number is $66.7 + 33.5 = 100.2$.

Iodine unites with bismuth when heated together, and the *iodide*, thus formed, has an orange yellow colour, is insoluble in water, but soluble in caustic potash.

Sulphuret of Bismuth.

DCXXVI. The sulphuret formed by melting the materials, is of a bluish gray colour, metallic lustre, crystallized in fine tetradral needles, resembling those of sulphuret of antimony. It is brittle and fusible. It is composed, according to Lagerhjelm, of 100 of metal, with 22.52 of sulphur; so that the sulphur, in this sulphuret, is just double the oxygen in the oxide. Its number is $15 + 66.7$.

Salts of Bismuth.

DCXXVII. *Nitrate of bismuth.* Bismuth decomposes undiluted nitric acid with great violence, and a dirty yellowish white powder is formed, insoluble in the acid. When the acid is considerably diluted, and the metal is added in small portions at a time, a solution, transparent, and of a faint green is produced. According to Dr. Thomson, as the liquid cools, it deposits small silvery crystals. I have never seen this, but they are formed readily by gently heating a solution of the nitrate, which is nearly neutral, even before any of the water is evaporated. These crystals attract moisture from the air, they deflagrate on burning coals, and detonate with phosphorus.

The solution of the nitrate, on the addition of water, becomes white and opaque, and deposits a powder, which was formerly called magistery of bismuth. It is said to be a *sub-nitrate*; and a super-nitrate remains in solution. The

greater the quantity of water employed the finer is the white. This compound is used as a paint for the complexion by the name of *pearl white*; but as it is somewhat acrid, it is said to be injurious, and the real cosmetic is a compound of tartaric acid and bismuth.

This sub-nitrate is used in medicine, for which purpose it requires to be prepared with care; the formula of Dr. Moore, of New-York, will perhaps be found the best to obtain it in its greatest purity, though the quantity of water is too large to render the process very convenient.*

The other salts of bismuth are of little consequence.

Alloys of Bismuth.

DCXXVIII. Bismuth combines with potassium. The alloy has the colour of bismuth, it is solid, very fusible, and brittle, and when broken presents the appearance of small facets. It is decomposed in the air, and it decomposes water with energy.

The colour of the alloy of bismuth and sodium is yellowish gray; it is less fusible than sodium, brittle, and presents, on fracture, a close grain.†

Iron, heated strongly with bismuth, becomes brittle. Native bismuth always contains this metal.

Bismuth does not combine with zinc. Its alloy with tin varies in properties, according to the proportions of the two metals. In equal parts, it is soft, and melts at 280° Fah. When the tin is in larger proportion it is less fusible, harder than tin alone, and brittle, and brought into contact with muriatic acid, the tin alone is dissolved.

Uses of Bismuth.

DCXXIX. They are very limited. It is employed in combination with some of the other metals in forming soft alloys,

* New England Journal of Medicine, vol. i. p. 234.

† Gay-Lussac and Thenard. *Recherches*, t. i. 219, 242.

which are used to *silver* the interior of glass globes ; to receive the impressions of medals, &c. It has sometimes been substituted for antimony in the formation of types, but it does not answer the purpose very well. Its oxide, as we have stated, is employed as a medicine, and as a paint.

SECTION XIII.

Of Copper.

DCXXX. This metal has been known from the earliest ages, and next to iron is the most valuable of this class of bodies.

It is of a fine red colour, and when polished, of considerable brilliancy. Its odour is disagreeable, and its taste nauseous. It is malleable, ductile, and tenacious ; it may be beaten into thin leaves, and drawn into fine wire, and a rod of this metal 0.078 of an inch in diameter will support a weight of 302 pounds. In hardness, copper is superiour to silver, and its specific gravity at a medium is 8.475.

Copper is fusible, and when exposed to a temperature of 27° Wedgewood, or 4560° Fah. it melts, and assumes colours, in which the green predominates. If the heat be increased, it evaporates in visible fumes ; and when subjected to a very intense temperature and in contact with the air, it burns with a lively green flame. It also burns in the circuit of a powerful voltaic battery, and in the flame of the oxy-hydrogen blow-pipe. When cooled slowly from its liquid state it may be obtained in quadrangular pyramids.

Copper with Oxygen.

DCXXXI. Copper, on long exposure to the air becomes covered with a substance of a green colour, which is an oxide in combination with carbonic acid. The metal is capable of uniting with two proportions of oxygen and of forming a protoxide, and a peroxide.

1. *Protoxide*. Mr. Chenevix discovered that the mineral called *ruby copper*, which is found native in the form of octoedra, is protoxide of copper; and he formed it artificially by triturating together in a mortar 57.5 parts of scales of copper, and 50 parts of precipitated copper, dissolving the mixture in muriatic acid kept in a close phial, and separating the oxide by potash; or by dissolving copper in muriatic acid, adding to the solution metallic copper, in a close vessel, and after all action had ceased, precipitating by potash.* The protoxide of copper is of a yellow colour, soluble in acids, and precipitable by the pure alkalies. Mr. Chenevix states the proportions in this oxide at 100 metal, and 12.9 of oxygen; by Berzelius they were found to be in the ratio of 100 + 12.5. The last is probably the most accurate. Hence its composition will be

		Prop.					
Copper	-	1	-	-	100	-	88.89
Oxygen	-	1	-	-	12.5	-	11.11
		<hr/>					<hr/>
		2					100.00

The equivalent number therefore of copper is 60, and that of the protoxide 67.5.

2. *Peroxide*. When copper is alternately heated red hot and plunged into cold water, a quantity of scales of a dark red colour is detached, which, on being heated in an open vessel, are converted to a black. They then constitute peroxide of copper. The same compound may be obtained by precipitating copper from its solution in some of the acids; a blue substance separates, which, when heated, gives off water and becomes black. Hence it exists in the state of hydrate, and combined, according to Proust, with about $\frac{1}{4}$ part of water. The peroxide is composed of

* Philosophical Transactions for 1812, p. 335.

		Prop.				
Copper	-	1	-	100	-	80
Oxygen	-	2	-	25	-	20
		<hr/>				<hr/>
		3				100

And will be represented by $60 + 15$.

Copper with Chlorine.

DCXXXII. Copper combines with two proportions of chlorine. When chlorine is admitted to filings of this metal in a close vessel, the latter becomes ignited, a fixed fusible substance quickly forms, and the vessel becomes lined with a sublimate of a fine yellowish brown colour. When the former is again heated in chlorine, it is converted into the latter. Hence there are 2 compounds of these substances.*

1. *Protochloride*. It may be obtained by burning copper in chlorine; by heating copper with corrosive sublimate; or by boiling copper filings in muriatic acid.

This chloride has the appearance and colour of resin, of a light yellow, semi-transparent, and crystallized apparently in small plates. It is fusible just below redness, but neither volatile, nor decomposable at the temperature of ignition; but if air be admitted it is dissipated in dense white fumes. It does not dissolve in water, but is soluble in muriatic acid, and again separated from it unaltered by water. It effervesces with nitric acid. This chloride, as commonly procured, is opaque, of a dark brown colour, and of a confused hackly texture. It consists, according to Dr. Davy, of 64 of copper and 36 of chlorine. This approaches within $\frac{18}{1000}$ of its theoretical composition, viz.

		Prop.				
Copper	-	1	-	100	-	64.18
Chlorine	-	1	-	55.83	-	35.82
		<hr/>				<hr/>
		2				100.00

Hence it may be represented by $60 + 33.5 = 93.5$.

* Dr. J. Davy. Nicholson's Journal, vol. xxxiii. p. 10.

2. *Perchloride*. May be obtained most easily by evaporating to dryness, at about 400° Fah. the deliquescent muriate of copper. It is of a yellow colour, pulverulent, deliquescent, and, on exposure to the air, changes to the deliquescent muriate; its colour during this change varies from yellow to white, and from white to green. It is decomposed by heat, and in a large quantity of chlorine. It is composed, according to Dr. Davy, of 47 of copper and 53 of chlorine. So that its composition may be stated at

	Prop.			
Copper	-	1	-	47.15
Chlorine	-	2	-	52.85
		<hr/>		<hr/>
		2		100.00

Its number is $60 + 67 = 127$.

Phosphuret of Copper.

DCXXXIII. It is in the form of 4-sided prisms, white, with a shade of gray, of a metallic lustre, brittle, and of great hardness. It consists of from 15 to 20 parts of phosphorus and from 80 to 85 of copper.

Sulphuret of Copper.

DCXXXIV. Sulphur combines readily with copper, and the compound may be easily formed by stratifying in a crucible, copper filings and flowers of sulphur, in the proportion of 8 of the former to 3 of the latter. The crucible is heated nearly red hot and should be covered. The two substances then unite, and at the moment of union the whole mass glows with a brilliant light, which is totally independent of the atmosphere. It is of a dark colour, bluish, of some metallic lustre, brittle, and more fusible than copper. According to the analysis of Berzelius, it consists of 100 of copper, and 25.6 of sulphur, which very nearly agrees with its theoretical

composition. Its number will be $60 + 15 = 75$, the same as that of the peroxide.

Salts of Copper.

DCXXXV. Chlorate. Peroxide of copper dissolves readily in chloric acid, and forms a solution which is green, and contains an excess of chloric acid. The salt is very deliquescent and therefore crystallizes with difficulty. It is melted and decomposed on burning coals, producing a green flame. A paper moistened with it, and held near the fire, burns with a green flame at a temperature lower than would be sufficient to burn the paper alone.*

Muriates of copper. Muriatic acid acts upon metallic copper slowly, but it dissolves the oxides with facility. The solution is of a fine green colour, and on evaporation produces prismatic crystals, of a beautiful silky green, deliquescent, soluble in water and alcohol, and of an acrid, metallic taste. When evaporated to dryness, it leaves perchloride of copper. The solution is decomposed by the alkalies, which produce a green precipitate; if more be added the precipitate is blue. This salt has been called *per-muriate of copper*.

The *protomuriate* is formed in the manner directed for the preparation of the protochloride. When metallic copper is added to solution of permuriate, and preserved from the air, the liquid becomes nearly colourless and deposits small whitish crystals. The same substance, which Proust named white muriate of copper, was procured by him by adding muriate of tin to solution of green muriate of copper.

Nitrate of copper. Copper decomposes nitric acid with great rapidity, and disengages abundance of nitric oxide gas. If the acid be diluted, the decomposition goes on more moderately, and a blue solution is obtained, which, on evaporation, yields long and slender prismatic crystals, of a dark blue col-

* Annals of Philosophy, vol. ix. p. 40.

our, of an acrid, metallic taste, very soluble in water, deliquescent in the air, melting in a moderate heat, and decomposable at a high temperature. It deflagrates on burning coals. It is decomposed by iron and zinc, which throw down the copper in its metallic state. The solid salt is decomposed with great energy by tin-foil, provided the powder of the salt have been previously moistened. Dr. Thomson states its composition at 100 of nitric acid and 148.148 of peroxide of copper. The alkalis precipitate the oxide in the form of hydrate.

When this salt is exposed to heat until it becomes thick, and encrusts the vessel with a green substance, it has lost a portion of its acid, and is converted into a subnitrate, which is insoluble in water.

Phosphate of copper is in the form of a powder, of a bluish green colour, and insoluble.

Sulphate of copper. Blue vitriol. This is the most useful and therefore the most important of the salts of copper, if we except, perhaps, the acetate. It is procured for the purposes of commerce from the native sulphuret.

It is of a fine blue colour, crystallized in rhomboidal prisms, of a styptic, acrid, and nauseous metallic taste. It acts upon the living fibre as an escharotic. This salt is soluble in about 4 parts of water at 60°, and in much less of boiling water. The solution is transparent and of a blue colour. It is slightly efflorescent, and has the property of reddening vegetable blues. Hence it contains an excess of acid, and is to be considered as a bi-sulphate. It is decomposed by heat, first losing its water of crystallization, and becoming a dry blue powder, and parting with its acid. Its constituent parts, as stated by Proust, are peroxide of copper 32, sulphuric acid 33, and water 35, with which the analysis of Berzelius very nearly coincides. The dry salt will therefore consist of

		Prop.				
Peroxide of copper	-	1	-	-	-	50
Sulphuric acid	-	2	-	-	-	50
		<hr/>				<hr/>
		3				100

united with 4 proportions of water, in the crystallized sulphate.

Solution of bi-sulphate of copper is decomposed by the alkalis, which precipitate the oxide in the form of hydrate; and by zinc and iron, which separate the copper in its metallic state.

The bi-sulphate of copper is used in the art of dyeing; and in medicine as an astringent and escharotic.

When the excess of acid in this salt is saturated with peroxide of copper, a neutral sulphate is formed, which crystallizes, according to Le Blanc, in 4-sided pyramids, separated by quadrangular prisms. In other respects it is similar in properties to the bi-sulphate. It of course contains but 1 proportion of acid.

According to Proust, a sub-sulphate of copper may be formed by adding a small quantity of potash to a solution of the bi-sulphate. It is separated of a green colour.

Sulphate of copper appears to have the property of combining with green sulphate of iron, apparently in certain proportions only. A solution of equal parts of these two salts yields tetraedral rhomboidal prisms of a greenish blue; and 3 parts of sulphate of iron, to 1 of sulphate of copper, produce, on evaporation, crystals of the same form, and of an emerald green colour.* M. Beudant likewise found, that when thus formed, the crystals were in the salts in the same proportion in which they were mixed. Thus crystals were obtained, containing 91 parts of sulphate of copper, and 9 of sulphate of iron; and of 72.75 of sulphate of copper, 24.25 of sulphate of zinc, and 3 of sulphate of iron, and yet all these crystals exhibited the form of the sulphate of iron. Dr. Wollaston likewise obtained crystals of 4 parts sulphate

* Berthollet's Chemical Statics, vol. i. note xiv.

of iron, and 1 of sulphate of copper, which had the exact form of sulphate of iron.*

These surcompounded salts, as Berthollet calls them, are considered by Dr. Wollaston as true chemical compounds.

Protoxide of copper combines with sulphurous acid.

Carbonate of copper may be formed by precipitating oxide of copper from its acid solutions by an alkaline carbonate. It is of a fine green colour. This compound is likewise found native, and constitutes the beautiful mineral, called *malachite* and *azure copper*. According to Dr. Thomson, it consists, independently of water, of 21.58 of carbonic acid, and 78.42 of peroxide of copper.

The oxides of copper also unite with phosphoric, fluoric, and boracic acids.

Arsenite of copper. It is formed by adding solution of arsenite of potash to solution of sulphate of copper; an insoluble arsenite of a fine green is precipitated. This compound is used in the arts by the absurd name of vegetable green; it is sometimes called Scheele's green. This pigment is prepared by dissolving 2 pounds of blue vitriol in 12 pounds of hot water, and adding to it a solution of 2 pounds of pearlash, which has been previously boiled with 11 ounces of arsenic of commerce in 4 pounds of water, until the latter has been dissolved. The precipitate is collected, washed with water, and dried.

Arseniate of copper. Arsénic acid digested with copper oxidizes it, and forms a green solution, and a powder of a bluish white precipitates, which is the arseniate. This compound exists native and presents several varieties.

Oxide of copper combines with the other metallic acids.

The salts of copper, as a genus, are distinguished,

1. By the blue or green colour of their solutions.
2. By the precipitation of their oxides and their subsequent solution, when liquid ammonia is added in considerable excess, forming a beautiful violet blue liquid.

* Annals of Philosophy, vol. xii. p. 27.

3. By yielding metallic copper when brought into contact with a plate of zinc or iron.

4. By a black precipitate being formed with an alkaline hydro-sulphuret.

5. By forming with ferruretted chyzate of potash, a fine brown precipitate.

Copper with Ammonia.

DCXXXVI. The action of ammonia on copper is peculiar. When a small quantity of liquid ammonia is added to sulphate of copper, a greenish blue precipitate is formed, which, on the addition of more ammonia, is redissolved. When peroxide of copper is immersed in liquid ammonia, it gradually dissolves and forms a violet coloured solution. If the metal be employed, it is necessary to use solution of carbonate of ammonia. The colouring matter may be obtained in the solid state, by triturating together 2 parts of sulphate of copper and 3 of carbonate of ammonia, the mass becomes moist, and effervesces from the disengagement of carbonic acid. The colour of the solid gradually changes to a fine violet. This compound has received the name of *Ammoniuret of copper*. It has been employed in medicine. It is doubtful whether this is to be considered as a ternary compound of sulphuric acid, ammonia, and oxide of copper; or a mixture of sulphate of ammonia and ammoniuretted oxide of copper; or of sulphate of ammonia and sulphate of copper. Berzelius considers the last as correct, and affirms that they exist in the proportions of 7.125 parts of sulphate of ammonia, 20.000 of bisulphate of copper, and 14.625 of water.

Alloys of Copper.

DCXXXVII. 1. Copper unites, though with difficulty, with iron, and forms an alloy of a gray colour, rather brittle, difficultly fusible, and of no use.

2. With zinc it unites in various proportions, and the combination is effected by exposing copper to heat with calamine

which is an ore of zinc, and charcoal ; or by the direct action of metallic zinc. In the former case the product is the well known and valuable article, *brass*. The colour depends upon the proportion of the zinc, the finest yellow being produced when it amounts to $\frac{1}{12}$ of the whole mass. According to Dr. Thomson, in English brass, the copper is to the zinc as 8 to 4.125 ; in Dutch brass, as 16 to 4.125.* Brass is of a fine yellow colour, more fusible than copper, capable of being beaten into finer leaves, is less liable than copper to rust, and therefore more permanent in the air, and more ductile and tenacious, by which it may be turned in the lathe, and be more easily manufactured. In the latter case, viz. when zinc is united directly with copper, and in larger proportion, alloys are formed which are known in the arts by the names of pinchbeck, prince's metal, similor, &c. all of which are applied to useful or ornamental purposes.

3. The alloys of copper with tin are not less valuable, and are familiarly known as the metal of bells, bronze, and artillery. Copper, in combining with tin, has its specific gravity increased, or rather it is greater than the mean of the two metals ; it loses, in some measure, its ductility, and acquires a greater degree of hardness, tenacity, and sonorousness. Its fusibility is likewise augmented. Bronze is composed of from 8 to 12 parts of tin, combined with 100 of copper. This composition was generally employed by the ancients for the same purposes, for which the moderns use iron and steel. Brass guns, as they are incorrectly called, are formed of the same alloy. It is more tenacious than cast iron, and hence less liable to break into fragments ; it is likewise much more sonorous. Bell metal is a compound of 3 parts of copper and 1 of tin. The Chinese *gong* was found by Dr. Thomson to be composed of 80.42 of copper, and 19.58 of tin. A compound metal susceptible, from its hardness, of a fine polish, and hence used for mirrors for reflecting telescopes, is formed of 52 parts of copper and 14.5 of tin.

* Annals of Philosophy, xii. 20.

Copper vessels, for culinary and other purposes, are coated with a thin film of tin, by heating them, then melting a little tin with a quantity of rosin, and applying the melted metal uniformly to the surface of the copper by means of a wad, or wire brush.

4. Copper forms an alloy with arsenic by melting them together in a covered crucible ; it is white and brittle, and is known in the arts by the name of white copper, or tombac.

SECTION XIV.

Of Uranium.

DCXXXVIII. This metal was discovered by Klaproth to exist in the minerals called Pechblendc, Green mica, and Uranitic ochre. Its oxide may be obtained from the first of these, which is a sulphuret, by the medium of nitric acid. This oxide is of very difficult reduction, and requires for that purpose a temperature which has been estimated as high as 170° of Wedgewood's pyrometer. Even by this heat it was obtained by Klaproth, and afterwards by Bucholz, either in imperfectly agglutinated grains, or in the form of a small button.

Uranium is of grayish colour, with some brilliancy, hard, but yields to the file, of a fine grain, and of specific gravity varying from 8.1 to 9. It is almost infusible by common means ; in Mr. Children's experiments its oxide was fused but not reduced.

Oxides of Uranium.

DCXXXIX. Uranium is capable of forming two oxides, but the proportions of oxygen have been very differently stated by chemists.

When uranium is exposed to heat in an open vessel, at the moment it combines with oxygen, it becomes heated to ignition, giving out light, and is converted into an oxide of a

grayish black colour. This has been considered as a protoxide.

When the metal is dissolved in nitric or nitro-muriatic acid, and the solution is decomposed by an alkali, a precipitate is formed, which, when washed and dried, is of a yellow colour, insipid, insoluble in water, but soluble in the acids. It is considered as a peroxide of uranium. On exposure to heat it becomes of a dark gray. Vauquelin affirms that there is an intermediate oxide of a green colour, which is soluble in the alkaline carbonates, and forms neutral salts with the acids, which is not the case with the peroxide.* The relative quantity of oxygen in these oxides has been so differently estimated by different chemists, that no reliance can be placed on the calculations, from which the equivalent number for uranium may be derived.

Uranium has not yet been combined with the other supporters of combustion, nor the combustible bases, if we except sulphur, with which it appears to form an imperfect or slight union.

Salts of Uranium.

DCXL. The saline compounds of this metal are but little known.

Nitrate of uranium is in the form of hexagonal tables, of a light green colour, very soluble in water and alcohol, and decomposable by heat.

Muriate of uranium crystallizes in rhomboidal tables, of a yellowish green colour.

With diluted sulphuric acid, oxide of uranium forms a solution, which yields prismatic or acicular crystals, of a lemon yellow colour, soluble in water and alcohol, losing its water at a red heat, and being decomposed at the temperature of whiteness.

The oxide likewise forms salts with the other acids.

* Nicholson's Journal, vol. xxv. p. 69.

The solutions of these salts are decomposed by the alkalis, the precipitate being yellow ; with the alkaline carbonates it is white. Ferruretted chyazate of potash occasions a reddish brown precipitate ; with hydro-sulphuret of potash it is brownish yellow ; and with infusion of galls, of the colour of chocolate.

The alloys of this metal have not been examined.

Uranium is applied to no use.

DIVISION V.

Metals which, when heated to a certain degree, absorb and retain oxygen, but again evolve it, at a higher temperature.

This division includes 4 metals, viz. Mercury, Lead, Nickel, and Osmium. The last is found with 3 other parasitical metals, in combination with platina, and I shall so far depart from the order here mentioned, as to describe the properties of osmium in the last division.

SECTION I.

Of Quicksilver or Mercury.

DCXLI. Mercury was known to the ancients ; its preparations were introduced into medicine by Paracelsus, and it is incredible how much mischief resulted from the ignorance and rashness of the alchemists and physicians.*

This metal at common temperatures is liquid, of a white colour with a shade of blue, opaque, and of high metallic brilliancy. In small masses, its shape is nearly spherical. Its specific gravity is 13.568. At the temperature of -39° it loses its fluidity, becomes solid, and diminishes $\frac{1}{23}$ of its bulk. In this state its texture is crystalline, it is malleable, and its specific gravity amounts to 14.465. When held in the hand it produces the sensation of a burn. During its congelation, mercury gives out a quantity of caloric equal to 152° of Fah.

On exposure to heat this metal expands, though with an increased ratio to the increments of temperature, until it rises to about 663° ; it then boils and may be distilled over in close vessels without alteration. The boiling point of mercury has been placed by Irvine at 672° ; by Crichton at 655° ; and by Dalton at 660° . The mean of these numbers

* John Woodal, in his *Viaticum*, London, 1653, gives many curious and remarkable instances of the injury sustained by society from the use of mercurial medicines.

is 663°. It evaporates slowly at a temperature considerably below that which is necessary to its active vaporisation. Chemists take advantage of this volatility in the purification of mercury. In commerce this metal is sometimes adulterated with lead, bismuth, &c. and the sophistication can be discovered and the mercury be obtained pure by distillation. The vapour, like that of every other liquid, is indefinitely expandible by heat.

Oxides of Mercury.

DCXLII. Mercury combines in 2 proportions with oxygen, and forms 2 distinct oxides.

1. *Protoxide*. By long agitation in contact with the air, a dark blue or black powder forms upon the surface of the metal, and it was first procured by Boerhaave, who enclosed a quantity of mercury in a phial, partly filled with air, tied it to a mill-wheel, and allowed it to revolve for several months. He called it *ethiops per se*. It is likewise said to be procured when potash in solution is poured upon calomel, a black powder is produced which is probably a mixture of the protoxide with metallic mercury. It is formed also during the trituration of mercury with farinaceous, and oleaginous bodies. From experiments it has been sufficiently proved that the elements in this protoxide exist in the ratio of 100 of metal to 4 of oxygen. Hence it is composed of

Mercury	-	-	1	-	-	100	-	-	96.154
Oxygen	-	-	-	1	-	-	4	-	3.846
									<hr/>
									100.000

The equivalent number of mercury, therefore, is 187.5, and that of its oxide 195.

2. *Peroxide*. When mercury is exposed for several days in succession to a degree of heat little short of its boiling point in a vessel which permits of a circulation of air, but

prevents the escape of vapour, its surface becomes covered with red, crystalline particles, which the earlier chemists designated by the name of *precipitate per se*. Common red precipitate, which will be described hereafter, is likewise a peroxide of mercury. Obtained by the action of heat, it is in crystalline plates or grains of a fine red colour, opaque, of considerable lustre, acrid to the taste, and soluble in a slight degree in water. It acts with energy on the living fibre. Exposed to heat, it gives out oxygen gas holding in solution, as it has been said, a small proportion of mercury, and leaves the metal in its metallic state behind. It combines with the acids and forms with them saline compounds. It has been demonstrated that this peroxide contains twice as much oxygen as the protoxide. It is composed, therefore, of

Mercury	-	^{Prop.} 1	-	-	100	-	-	92.593
Oxygen	-	2	-	-	8	-	-	7.407
		<hr/> 3						<hr/> 100.000

And will be represented by $187.5 + 15 = 202.5$.

Chlorides of Mercury.

DCXLIII. When mercury is introduced into chlorine gas and gently heated, it takes fire and burns with a pale red flame, and forms a chloride, in which the metal exists in the ratio of 1 of mercury to 2 of chlorine. Another compound may be formed which contains but 1 proportion of each, so that there are a chloride and a bi-chloride of mercury.

1. *Chloride. Calomel. Sub-muriate of mercury.* This important compound may be prepared in two ways. 1. By rubbing together in a mortar 4 parts of corrosive sublimate and 3 of quicksilver, until the globules of the latter have disappeared, the whole assumes the appearance of a grayish black mass. The mixture is then to be sublimed in

a glass vessel; and after separating the white matter concreted in the upper part, from that which remains at the bottom, it is to be exposed to a second sublimation, and afterwards triturated under the surface of hot water. 2. By pouring a solution of common salt acidulated with a little muriatic acid, into a solution of mercury in nitric acid, which has been made without the application of heat, collecting and washing the precipitate with large portions of warm water and then drying it.

Calomel, or chloride of mercury, is in the form of a dense yellowish white mass, which may be crystallized in tetradral prisms, terminated by pyramids. It is nearly destitute of taste, insoluble in alcohol and water, and of a specific gravity amounting to 7.1758. By the action of light, it acquires a deeper tint of yellow. It is volatile in a strong heat, and rises in vapour without alteration. Chlorine gas converts it into bi-chloride. The alkalies decompose it, and according to M. Guibourt, convert it into metallic mercury by abstracting its chlorine; the same effect is produced by some of the metals of the second division; and by some of those of the third and fourth divisions when aided by heat. Calomel is composed in round numbers of 85 parts of metal and 15 of chlorine; or by calculation of

	Prop.								
Mercury	-	-	1	-	-	100	-	-	84.85
Chlorine	-	1	-	-	-	17.33	-	-	15.15
			<hr/>						<hr/>
			2						100.00

And it may be represented by $187.5 + 33.5 = 221$.

2. *Bi-chloride of Mercury. Corrosive sublimate.* It is this compound which is formed when mercury is burned in chlorine. For the purposes of commerce, it is obtained by an indirect process, by exposing to a subliming heat, in a close vessel, equal weights of common salt, and sulphate of mercury. Other methods, but on the same principle, yield the bi-

chloride; and it may be formed directly by the action of chlorine on a solution of nitrate of mercury.

Corrosive sublimate, or bi-chloride of mercury, is a fine white mass composed of small prismatic crystals, translucent, of a very acrid, nauseous taste, and highly poisonous, producing, when swallowed, inflammation and erosion of the stomach and alimentary canal. It is soluble in about 20 parts of cold water, and $\frac{1}{2}$ its weight of boiling water. Alcohol at 60° takes up nearly $\frac{3}{8}$ of its weight. It is deposited from its saturated aqueous solution, as it cools, in long and slender quadrangular prisms of a beautiful white. It is volatile at a temperature lower than is required for the sublimation of calomel.

Solution of bi-chloride of mercury is decomposed by the alkalis and alkaline earths, and a precipitate of an orange colour, which in a few minutes changes to a full red, is produced. The salt itself is soluble in several of the acids without decomposition. It is decomposed by ammonia, which gives a white precipitate, and by the hydro-sulphurets and sulphuretted hydrogen. This chloride contains twice as much chlorine as the chloride. Hence it consists of

	Prop.					
Mercury	-	1	-	-	100	- - 73.72
Chlorine	-	2	-	-	35.64	- - 26.28
		<hr/>				<hr/>
		3				100.00

And its number is $187.5 + 67 = 254.5$.

Iodides of Mercury.

DCXLIV. Mercury and iodine combine with great facility, and form two compounds, the one yellow, and the other a fine red; the former consists of 1 proportion of each, the latter of 1 proportion of metal and 2 proportions of iodine. They are both insoluble in water, and decomposable by nitric acid. They are likewise volatile and fusible.

Phosphuret of Mercury.

DCXLV. The combination of mercury with phosphorus was effected by Pelletier, by exposing to heat under water, 2 parts of red precipitate, and $1\frac{1}{2}$ of phosphorus. This phosphuret is a solid substance, black, tenacious, fusible, and decomposable on exposure to the air.

Sulphurets of Mercury.

DCXLVI. As mercury combines in 2 proportions with oxygen, chlorine, and iodine, so it is capable of forming 2 compounds with sulphur.

1. *Sulphuret, or proto-sulphuret. Ethiops mineral.* It is prepared by triturating together equal parts of sulphur and mercury; by adding the metal by small portions at a time to melted sulphur; or by precipitating mercury from some of its acid combinations by sulphuretted hydrogen. This compound is the black sulphuret, or the ethiops mineral of the older physicians.

2. *Per-sulphuret, or bi-sulphuret. Cinnabar.* To form this compound, 1 part of sulphur is triturated with 7 or 8 of mercury, the mixture is inflamed, and the resulting mass, on being exposed to a subliming heat in a close vessel, rises in vapour, and attaches itself to the superior surface in the form of a dense crystalline cake, formed of prisms, of a fine red colour, insipid, insoluble in water, and of a specific gravity amounting to 10. This is cinnabar or red sulphuret of mercury. When properly levigated, it is converted into the pigment called *vermillion*.

With respect to the composition of these sulphurets, the proto-sulphuret appears to be a compound of about 100 of metal and 8 of sulphur, and the per-sulphuret of $100 + 16$. Hence the sulphur in the first is double the oxygen in the protoxide. They may be represented respectively by 202.5 and 217.5.

Cyanide of Mercury.

DCXLVII. This compound, the *prussiate of mercury* of chemists, may be prepared by boiling 2 parts of prussian blue in powder, and 1 part of peroxide of mercury, in 8 parts of water, until the red colour of the oxide disappears. The solution is filtered, and a small quantity of hot water is poured upon the residue, which is allowed to pass through the filtre. The liquid is then evaporated to a certain degree, and on cooling deposits the cyanide in crystals. As commonly prepared they are of a reddish colour, owing to the presence of oxide of iron. When freed from this, cyanide of mercury is in the form of long, transparent, and colourless quadrangular prisms, of a styptic and intensely bitter metallic taste. It is poisonous. It is soluble in water. Exposed to heat in its dry state, the cyanide blackens, melts, and is then decomposed, cyanogen gas is evolved, part of the cyanide sublimes, and a black and light charry matter remains. If the compound be moist, the results of its distillation are hydro-cyanic vapour, ammonia, and carbonic acid.

Cyanide of mercury is soluble without decomposition in a hot solution of pure potash, and is separated in crystals when it cools. The hydracids in their action on the cyanide produce hydro-cyanic acid. The cyanide of mercury is composed of 100 of mercury and 26.15 of cyanogen.

Its solution dissolves without decomposing peroxide of mercury, and forms a salt which is very alkaline, more soluble than the simple cyanide, and crystallizing in small tufts. It is so easily carbonized that it requires to be dried at a very moderate heat. Hence this salt was called by Proust a *sub-prussiate*. It may be converted into cyanide of mercury by the addition of strong hydro-cyanic acid.

Salts of Mercury.

DCXLVIII. *Chlorate of mercury.* This salt contains protoxide of mercury. It is in the form of grains, of a yellow-

ish colour, has a metallic taste, and is soluble, though sparingly, in water. It explodes when heated, gives out oxygen gas, and the residue is bi-chloride of mercury.

Nitrate of mercury. There are two salts of this name ; one contains the protoxide, and the other the peroxide.

1. When mercury is added to diluted nitric acid in small portions at a time, and the solution is allowed to go on without the application of heat, the acid dissolves more than its own weight of the metal, and forms a colourless solution, which is ponderous and caustic. On evaporation it yields octoedra crystals, the apices and the angles at the bases of the pyramids being often truncated. It is soluble in water, and this liquid added to its solution when first formed, produces no decomposition. Sulphuretted hydrogen gas, and proto-muriate of tin decompose it, in the first case sulphuret of mercury, and in the second, metallic mercury being precipitated. This salt may be called the *nitrate of mercury*.

When mercury is boiled in nitric acid, diluted with an equal weight of water, much nitric oxide gas is disengaged, and a solid salt is deposited as the solution cools. On the addition of water the liquid acquires a white and opaque appearance, sub-nitrate of mercury is precipitated, and a super-nitrate remains in solution.

2. Mercury decomposes concentrated nitric acid with energy, particularly when aided by a gentle heat, and after the action has ceased a large proportion of the mass becomes a crystalline and yellowish solid. The solution is ponderous and caustic, and contains peroxide of mercury united with the acid. Hot water poured into it, precipitates a yellowish powder, which was called by the old chemists nitrous turpeth or turbith.

All the solutions of mercury in nitric acid, just mentioned, contain an excess of acid. The most perfect salt may be formed by the direct solution of peroxide of mercury in nitric acid.

From these solutions of mercury several important medicinal preparations may be obtained.

1. When they are evaporated to dryness and the solid salt is exposed to heat, it first acquires a yellow colour, and is then converted into a mass of a fine red colour, and of a scaly semi-crystalline appearance, which is familiarly known by the name of *red precipitate*. It is considered by some chemists as peroxide, and by others as a sub-nitrate of mercury. Much care however is requisite to develop the genuine colour.

2. Ammonia, when poured into the solution which is made without the aid of heat, produces a precipitate of an ash colour, which is designated in the modern pharmacopœias by the name of *Oxidum Hydrargyri Cinereum*. The use of the ammonia in part is partially to deoxidize the mercury and convert it into protoxide. If ammonia be added to the solution of mercury in concentrated nitric acid, the precipitate will be white, and it has been shown by Fourcroy to be a ternary compound of ammonia, oxide of mercury, and nitric acid.

3. The nitric solutions are decomposed by muriatic acid, or common salt, and form calomel. Some cautions, however, are required in these processes.

These solutions are likewise decomposed by the fixed alkalis, and the alkaline earths ; if the metal be in the state of protoxide, the precipitate is yellowish gray ; if in that of peroxide, it is yellowish white.

Carbonate of mercury, a white, insoluble powder, formed by pouring solution of an alkaline carbonate into a nitric solution of mercury.

Phosphate of mercury, obtained by means of an alkaline phosphate, is a white powder, phosphorescent in the dark by friction, and yielding phosphorus when distilled with charcoal.

Sulphate of mercury. The combinations of sulphuric acid with the oxides of mercury present some interesting results. They do not act upon each other while cold, but if heated to the boiling point of the acid, a portion of the latter is decomposed, the mercury becomes oxidized, and combines with the remaining acid, while pure sulphurous acid is disengaged. A

white crystalline mass is obtained, which, if washed with water, leaves a *neutral sulphate*. The same compound may be formed by boiling mercury in $1\frac{1}{2}$ times its weight of acid, diluted with an equal weight of water. The solution on cooling, or by evaporation, yields prismatic crystals, soluble in 500 parts of water, and acrid to the taste. Its composition may be stated at

	Prop.	
Oxide of mercury	1	80.92
Sulphuric acid	1	15.56
Water	1	3.52
	<hr/>	<hr/>
	3	100.00

It must be represented by $195 + 37.5 + 8.5 = 241$.

When 2 parts of sulphuric acid are boiled in 1 part of mercury nearly to dryness, a white, crystalline mass is obtained, which is acid and acrid to the taste, deliquescent, and soluble in water. It may likewise be formed by combining sulphuric acid with the neutral sulphate. It is a *bi-sulphate*, and contains two proportions of acid.

If instead of stopping the process before the whole of the acid has disappeared, the application of heat be continued, the acid is gradually decomposed, the peroxide in combination with sulphuric acid is formed, and the result is a fine white mass, crystallized in small and delicate prisms, permanent in the air, and composed of

	Prop.	
Peroxide of mercury	1	70.72
Sulphuric acid	2	26.31
Water	1	2.97
	<hr/>	<hr/>
	4	100.00

This salt is decomposed by water, a super-sulphate is dissolved, and a sub-sulphate precipitated. This sub-sulphate

is the old *turpeth* or *turbith mineral*. It is the Subsulphas Hydrargyri Flavus of the modern pharmacopœiæ. It is prepared for medicinal purposes by pouring boiling water upon the perfectly dry sulphate, and mixing them by agitation. It is of a fine yellow colour, soluble in 2000 parts of cold water and 600 of water at 212° , its specific gravity is 6.4. This sub-sulphate operates with great energy on the human system. It is composed of

	Prop.				
Peroxide of mercury	1	-	-	-	34.38
Sulphuric acid	1	-	-	-	15.62
	<hr/>				<hr/>
	2				100.00

And may be represented by 240.

All the varieties of this salt are decomposed by the alkalis and earths.

Mercury likewise combines with the metallic acids.

Fulminating Mercury.

DCXLXIX. Bayen discovered that the oxides of mercury, precipitated from their acid combinations by the alkalies, acquired an explosive property when triturated with about $\frac{1}{8}$ their weight of sulphur, and gently heated.* It has since been proved by Mr. Howard that a powerful fulminating compound may be produced by the reciprocal action of mercury, nitric acid, and alcohol.† His method of preparing it is as follows; one hundred grains of quicksilver, or a greater proportional quantity, not exceeding 500 grains, are to be dissolved in a measured ounce and a half of nitric acid, of the specific gravity of 1.3. This solution being poured cold upon two measured ounces of alcohol, specific gravity 0.849, previously introduced into any convenient glass vessel, a mode-

* Opuscles Chimiques, t. i. p. 346.

† Nicholson's Journal, 4to, vol. iv. p. 173.

rate heat is to be applied until an effervescence is excited. A white fume then begins to undulate on the surface of the liquid ; and the powder will be gradually precipitated. It is to be immediately collected upon a filtre, well washed with distilled water, and carefully dried in a heat not much exceeding that of a water bath. Immediate washing is necessary, otherwise the nitric acid present reacts upon the mass ; it is also to be remembered that the mercurial solution is to be poured upon the alcohol. The product from 100 grains of mercury amounts to from 120 to 132 grains. Brugnatelli affirms that a similar compound may be formed by adding to the yellow sub-sulphate of mercury 4 times its weight of alcohol, and 5 times its weight of nitric acid, effervescence is produced, and a solid exploding substance precipitated.*

Fulminating mercury explodes with violence by percussion. The report from 2 or 3 grains is very loud and sharp. When exploded in larger quantities it produces depressions both in the hammer and anvil. The explosion is likewise occasioned by friction, by the spark from flint and steel, by electricity, and by a temperature equal to 368° Fah. When sufficiently heated, the explosion is not so loud as that produced by percussion, but a vivid flash may be perceived. It operates with immense force, but the circle of its power is very limited ; hence Mr. Howard suggests that it might be employed for the purpose of splitting cannon &c. for which, by his experiments, it appears to be admirably adapted, were it not that its disposition to explosion renders its use dangerous.

According to Mr. Howard, fulminating mercury is a compound of oxide of mercury, oxalic acid, and nitrous etherized gas ; and the explosion is the result of the formation of carbonic acid and aqueous vapour, and the volatilization of the metallic mercury.

* Tilloch's Magazine, vol. xvi. p. 186.

Alloys of Mercury.

DCL. The compounds of mercury with the other metals are called *Amalgama*. They are for the most part white, crystallizable, solid, brittle, very fusible, and decomposable by heat, the mercury being evolved.

It readily combines with potassium and sodium, and the combination is attended with increased temperature. One part of potassium will coagulate or render solid no less than 70 of mercury. The amalgam is white and of a crystalline texture; and is rapidly decomposed by air or water.

Mercury does not act upon iron, but an imperfect amalgam, according to Mr. Aikin, may be formed, though with difficulty. It readily combines with zinc in different proportions, constituting a brittle amalgam, which, when reduced to powder and applied on leather, is employed to excite electrical machines. Amalgam of tin may be produced with ease, and a compound of this kind is employed for coating the backs of mirrors. A tin plate, or a sheet of tin-foil, is placed upon a table guarded by ledges, mercury is poured over it and spread uniformly by means of a wad; the mercury combines with the tin and forms an amalgam. The plate of glass is slid over the surface and pressed down by weights. In the course of a few hours the glass is raised on one end, the fluid mercury runs off, and a thin film of the amalgam remains adhering to the surface.

Mercury amalgamates with great ease with bismuth, and if the former considerably predominate, the compound is fluid. This amalgam, united with tin and lead, is employed in consequence of its easy fusibility, in coating the internal surfaces of glass globes.

Mercury is employed for a variety of useful purposes in the arts; and no other metal has afforded so many powerful preparations to the *materia medica*.

SECTION II.

Of Lead.

DCLI. The appearance of Lead, says Fourcroy, is sad, and it seems to announce its dangerous qualities. Its preparations are insidious poisons.

Lead is of a livid blue colour, with considerable lustre, and of a disagreeable odour when rubbed between the fingers. It is nearly destitute of ductility, and has so little tenacity that a rod of this metal $\frac{1}{16}$ of an inch in diameter, will support a weight of only 29 pounds; it is malleable however, and may be beaten into thin leaves. Its softness is such, that it may be scratched by the nail and cut with a knife, and bent in any direction. It is flexible but not elastic. The specific gravity of lead is 11.352.

Exposed to heat it melts, according to Irvine, at 594° ; and according to Crichton, at 612° ; and on being cooled slowly, may be obtained crystallized in quadrangular pyramids. It does not conduct heat and electricity so well as some of the other metals. In a very high heat lead is volatilized.

Lead does not act upon water, but when long immersed in it acquires upon its surface a white crust, which has been regarded as a compound of the atmospheric oxygen contained in the water with the metal.

Lead with Oxygen.

DCLII. When lead is exposed in its melted state to the air, its surface soon becomes covered with a gray pellicle, which, if removed, is succeeded by another, until the whole is converted into what is familiarly called *dross*. It is a mixture of metallic lead and the protoxide. When this pellicle is heated, it is converted into the massicot of commerce. This is regarded as the protoxide of lead.

It may likewise be obtained by precipitating nitrate of lead

by potash or ammonia, drying the solid, and heating it nearly to redness.

1. The protoxide is a powder of a yellow colour, insipid, insoluble in water, but soluble in acids and alkalies; and when exposed to heat, melts into a yellow glass. From the results of many experiments by different chemists, it may be stated to consist of lead 100, and of oxygen 7.5.

2. When nitric acid is poured upon red lead, an effervescence takes place, heat is evolved, and part of the mass is dissolved, while the other part is converted into a powder of a lively brown colour. It constitutes the peroxide or puce coloured oxide of lead. It may be prepared likewise by passing a current of chlorine through a mixture of red lead and water, until the former is dissolved. The solution is then decomposed by potash, and peroxide of lead is separated. It has a fine brown colour, is insoluble in water, and in nitric and sulphuric acids, but decomposes muriatic acid. Exposed to heat, it loses, during its conversion into the yellow oxide, about 7 parts of oxygen. Hence it would appear to contain double the quantity of oxygen which exists in the yellow oxide. But when massicot is exposed to heat in a reverberatory furnace, and constantly stirred, so as to bring the whole successively in contact with the air, its colour gradually changes to a red, which grows more intense until it becomes of a fine scarlet. It then constitutes Red Lead. When massicot is so managed as to become semi-nitrified, it is changed to an orange red substance, called Litharge. Now, from the experiments of chemists, it appears that red lead contains a quantity of oxygen, differing in proportion from that in the yellow or brown oxide; the quantity being stated between 10.5 and 11.08 to 100 of metal. Hence if this substance be considered as a definite oxide, the oxygen in the three compounds must be in the ratio of 1, $1\frac{1}{2}$, 2; or of 2, 3, 4. The yellow oxide, therefore, must be regarded as a deutoxide, the red as a tritoxide, and the brown as a tetroxide, as stated by Sir H. Davy. Or a different view may be taken of

them ; the red may be considered as a mixture or compound of the yellow and the brown oxides. But this opinion is not very plausible.

Red lead is a heavy powder of an intensely red colour, which is diluted by mixture with a small proportion of chalk. It is partially decomposed by heat, and sulphuric acid, oxygen gas in both instances being given off, and the oxide passing into massicot. In a very strong heat it is converted into a glass. All the oxides are reduced by being heated in contact with charcoal.

Red lead and massicot are employed as pigments.

Lead with Chlorine.

DCLIII. When lead is heated in chlorine it does not inflame, but a combination takes place and a chloride is formed. It may likewise be produced by pouring muriatic acid, or a solution of common salt, into solution of nitrate of lead ; or by heating oxide of lead in muriatic acid gas. This chloride, after being melted, has a grayish appearance, is semi-transparent, or translucent, fusible below ignition, and volatile at a high heat, and from its resemblance to horn was called by the older chemists *plumbum corneum*. Its taste is sweetish, and according to Sir H. Davy, it is soluble in 22 times its weight of water. It is the *muriate of lead* of modern chemistry. Sir H. Davy states its composition at 1 proportion of lead, and 2 proportions of chlorine.* According to Dr. John Davy, it consists of 72.22 of the former and 25.78 of the latter.† It is probably a bi-chloride.

The chloride or sub-muriate of lead is formed by making a paste with water of 1 part of common salt and 4 parts of litharge, and allowing it to remain for some time exposed to a moist air. Carbonate of soda forms, and when washed away, there remains a substance of a yellow colour, which, after

* Elements, p. 397.

† Philosophical Transactions for 1812, p. 185.

being melted and cooled, has a crystalline texture, is opaque, and heavy. It is the pigment called patent yellow. In this experiment the oxygen of the oxide appears to be transferred to the sodium, and the chlorine of the salt to the lead or base of the oxide.

Iodide of Lead.

DCLIV. This compound may be formed by heating its elements together ; or by decomposing a salt of lead by hydriodate of soda ; in either case a substance of a beautiful orange yellow colour, insoluble in water, is obtained.

Phosphuret of Lead.

DCLV. It is of a bluish white, with much brilliancy, which soon disappears on exposure to the air. It is soft, flexible, and of a lamellated texture. Exposed to heat it is partially decomposed, phosphorus being sublimed. It consists, according to Pelletier, of from 85 to 88 of lead, and from 12 to 15 of phosphorus.

Sulphuret of Lead.

DCLVI. Lead combines in 2 proportions with sulphur. The sulphuret exists native and is called Galena. It may be formed artificially by heating the two substances together. It is of a dark gray colour, with a metallic lustre, brittle, striated in its texture, and less fusible than lead. It contains about 15 per cent. of sulphur, and consists of 1 proportion each of its elements.

The bi-sulphuret also exists native ; and it is said may be formed by heating the sulphuret with sulphur. Its properties are similar to those of the sulphuret.

Salts of Lead.

DCLVII. *Chlorate of lead* crystallizes in brilliant plates, which melt and are decomposed on burning coals. When

distilled, it gives out oxygen gas mixed with a small proportion of chlorine. It is decomposed by the acids, which form insoluble compounds with its oxide.

Nitrate of lead. The compounds of oxide of lead with nitric acid have been much investigated by chemists, particularly by Chevreul and Berzelius. There appear to be 2 nitrates, and in both the acid is in combination with the yellow oxide.

1. *Nitrate.* Nitric acid, a little diluted, oxidizes lead and combines with its oxide with facility by the aid of a moderate heat. The solution yields, on evaporation, crystals which vary in form according to the quantity of water present; but among these the octoedron predominates. They are white, translucent, and of a soft pearly lustre. They deflagrate on burning coals, and are decomposed by heat alone. Its solution is decomposed by the alkalies, alkaline earths, hydro-sulphurets, and sulphuretted hydrogen. Its constituents, according to Chevreul, are 67 parts of oxide of lead, and 33 of nitric acid. Berzelius states the proportions at 67.23 of the former, and 32.77 of the latter.

2. *Sub-nitrate.* This variety may be formed by boiling yellow oxide of lead in a solution of the nitrate. It crystallizes in pearl coloured scales, of a sweetish, astringent taste, soluble in water, and containing 1 proportion each of acid and base; while in the nitrate there are 2 proportions of acid.

It has been proved also by Proust, Chevreul, and Berzelius, that oxide of lead combines with nitrous acid, and forms in one proportion a nitrite, in another a sub-nitrite.

Carbonate of lead. Carbonic acid exerts no action on metallic lead, but it unites readily with the yellow oxide, and the carbonate may be easily formed by adding an alkaline carbonate to solution of nitrate, or acetate of lead. In this form it is a white, insipid, and insoluble powder. It is prepared in the large way for the purposes of commerce by the agency of vinegar upon sheets of lead, it then constitutes the pigment called Cerusse or White Lead. It is usually mixed with

powdered chalk. This salt is likewise found native, semi-transparent, of a pearly lustre, heavy, and crystallized in the form of a table, six-sided prism, or octoedron. It is composed of 83.5 of oxide of lead and 16.5 of carbonic acid.

Phosphate of lead. Phosphoric acid acts upon lead with little energy. The phosphate may be formed more expeditiously by decomposing nitrate or acetate of lead, by phosphate of soda. It is white, insoluble in water, but soluble in solution of soda, and in nitric acid. It is decomposed by muriatic and sulphuric acids. It consists, according to Berzelius, of 76 parts of oxide and 24 of acid.

These two substances also unite in different proportions and form a super-phosphate and sub-phosphate.

Sulphate of lead. Sulphuric acid is decomposed at its boiling point by lead, sulphurous acid gas is given off, the metal becomes oxidized, and combines with the undecomposed acid. It may be formed at once by decomposing a salt of lead by sulphuric acid alone, or by an alkaline sulphate. It is a white and heavy powder, requiring 1200 parts of water for its solution. It is not soluble, like the phosphate, in nitric acid ; but may be dissolved in muriatic acid by heat, or rather partially decomposed by it, the solution yielding muriate of lead. According to Berzelius, it consists of 73.68 of yellow oxide, and 26.32 of acid.

From the strong affinity of its proximate elements, and the insolubility of the compound, the salts of lead, particularly the nitrate, are employed as tests of the presence of sulphuric acid.

Sulphate of lead is found native.

The oxide of lead unites with the metallic acids and forms peculiar compounds. Some of them are found native, and constitute minerals of great beauty, particularly the chromate or red lead ore of Siberia.

The salts of lead, as a genus, are distinguished by the following properties.

1. Those which are soluble have a taste at first sweet, and afterwards astringent ; hence the best known of these salts has acquired the name of Sugar of Lead. It is the acetate.

2. They all afford a dark brown or black precipitate with sulphuretted hydrogen. This is a delicate test, and one species of sympathetic ink may be formed by writing on paper with a solution of the nitrate or acetate, and holding it over a phial containing a solution of sulphuretted hydrogen, or a hydro-sulphuret. The same effect, it should have before been stated, is produced by nitrate of bismuth. Hence sulphuretted hydrogen has been employed to detect the presence of a salt of lead in wines, particularly those which become acescent by age, such as those of France and the South of Europe. Sugar of lead has sometimes been added to such wines to conceal, by its sweetish astringent taste, the acidity which they are apt to acquire. A recently made solution of sulphuretted hydrogen in water, poured into such liquids, produces a blackish precipitate, which, when dried and heated before the blow-pipe, exhales a sulphureous odour, and leaves a button of lead.

3. The precipitate from ferruretted chyzate of potash and infusion of galls is white.

4. A salt of lead, before the blow-pipe on charcoal, yields a button of metallic lead.

5. Metallic zinc occasions a precipitate either of lead itself, or of a white powder.

Alloys of Lead.

DCLVIII. Lead will combine with potassium when melted. The alloy is solid, very fusible, and brittle, its fractured surface being fine granular. It is decomposed in the air, and effervesces briskly in water.

The alloy with sodium is bluish gray, somewhat ductile, of a fine grain, and nearly as fusible as lead.*

* Gay-Lussac and Thenard.

Imperfect alloys are formed between lead and iron, and lead and cobalt. With tin it produces a compound of some importance. When melted together in the proportion of 3 parts of tin to 1 of lead, the alloy is harder than tin, and not so liable to be acted upon by other agents as lead. It then constitutes *Pewter*. Tin-foil contains a small proportion of lead. An alloy formed of 8 parts of bismuth, 5 of lead, and 3 of tin is so fusible as to melt in boiling water. Hence it is commonly called *Fusible metal*. When 1 part of mercury is added to this alloy, the compound may be melted over a lamp upon paper. Lead forms an alloy with bismuth, and what is remarkable, this alloy is so soluble in mercury, as little, if at all, to impair its fluidity, though the sophistication by lead alone would be immediately recognized by the imperfect form of the globules of mercury. The compound of lead and copper is of a gray colour; the amalgam of lead is liquid or solid, according as either metal considerably predominates over the other.

Uses of Lead.

DCLIX. Lead is a valuable metal. In its metallic state it is employed in the construction of pipes for the conveyance of water; in covering buildings; in the formation of boilers, and in the manufacture of small shot. Its oxides are used as pigments, and in the formation of flint glass, to which they impart a great degree of density, lustre, and refractive power. Hence they always enter into the composition of pier glasses, chandeliers, glasses for optical instruments, and in imitation of the precious stones. But at the same time they render the vitreous compound soft, and frequently give to different portions of the same mass different powers of refraction; a circumstance which is owing to the difficulty of keeping the glass of lead uniformly diffused through the other materials in their liquid state. The oxides of lead constitute the glazing which covers the surface of vessels of stone-ware. Hence arises the danger of using for food, acid, or acescent

articles after having stood for some time in contact with vessels of this kind. Some of the salts of lead are used in commerce as pigments, and others constitute articles of the *materia medica*.

SECTION II.

Of Nickel.

DCLX. Nickel, obtained by very complicated processes from the mineral called Kupfer-nickel,* is a metal of a white colour, susceptible of a good polish, capable of being drawn into fine wire, and of being beaten into leaves $\frac{1}{100}$ of an inch in thickness. Its specific gravity is 8.279, and when hammered, 8.66. It is not quite so hard as iron.

Nickel in common with iron possesses the power of being attracted by the magnet, and of acquiring magnetic polarity; and its power in this respect is to that of iron as 35 to 55.† The French philosophers have had needles constructed of this metal, and it is to be preferred to steel or iron, as it is little, if at all, altered on exposure to the air.

Nickel is one of the most infusible of the metals, its melting point being placed at 160° of Wedgewood.

Oxides of Nickel.

DCLXI. Nickel combines with two proportions of oxygen and forms two distinct oxides.

1. *Protoxide*. When exposed to heat and atmospheric air, nickel loses its lustre, and gradually becomes oxidized at the surface. The same oxide may be precipitated from nitrate of this metal by an alkali, either potash or soda; the precipitate is green, but on being heated to redness becomes brown. The

* See Kirwan's Mineralogy, vol. ii. p. 257. Philosophical Magazine, xvi. 312, and vol. xx, 63. Nicholson's Journal, iii. 287. Annales de Chimie, liii. 164.

† Lampadius. Annals of Philosophy, v. 62.

green coloured substance is the protoxide in combination with water. This oxide is the basis of the salts of nickel. It is soluble in ammonia and forms a violet blue solution. When precipitated from its combinations it is green, and the same colour characterizes its saline solutions. According to the late experiments of Rothoff, it consists of 100 of metal and 27.25 of oxygen.

2. *Peroxide.* The peroxide of nickel may be obtained from the protoxide by the medium of chlorine, or oxy-muriate of lime. It is black, gives off oxygen on exposure to heat, and by the action of acids, and is converted into the protoxide. It contains, according to Rothoff, $1\frac{1}{2}$ times as much oxygen as the protoxide. Hence the first is a dentoxide and the second a tritoxide, the latter being composed of 100 of metal and 40.88 of oxygen.

Nickel combines with chlorine and forms an olive coloured substance, and when muriate of this metal is decomposed by heat, some white brilliant scales are formed, which, according to Mr. E. Davy consist of these two elements.

Phosphuret of nickel is black and has a metallic lustre; when heated the phosphorus burns and the metal is converted into an oxide.

The sulphuret of nickel is yellow, hard, and presents brilliant facets.

Salts of Nickel.

DCLXII. Nitric acid dissolves nickel and forms a solution of a fine green colour, which, on evaporation, yields crystals of a rhomboidal figure, at first deliquescent, but afterwards falling into a powder in consequence of losing its acid. It is partially decomposed by heat. It consists of 55 of nitric acid, 25 of protoxide, and 20 of water. The solution of this salt is decomposed by the alkalies, which precipitate the oxide green; if added in excess it is redissolved. Ammonia produces phænomena similar to those exhibited by the salts

of copper. It first separates the oxide, then dissolves it, and produces a violet blue liquid ; but, unlike the analogous compound of copper, it changes from a blue to a purple, and then to a violet. If nitric acid be added, the green colour is restored, which may again be changed to a blue by ammonia. Mr. Phillips affirms that this blue solution may be decomposed by a fixed alkali, and the metal be always separated in this way from cobalt.*

Muriatic acid dissolves nickel with great difficulty ; the solution when made is green, and yields deliquescent crystals.

Sulphuric acid by the aid of heat is decomposed by this metal. The sulphate crystallizes in small prisms of an emerald green colour.

The salts of nickel are characterized by their green colour ; by producing a black precipitate with hydro-sulphuret of potash ; by the white precipitate occasioned by prussiate of potash ; and by being affected neither by infusion of galls, nor by sulphuretted hydrogen.

Nickel combines with several of the metals, but the alloys have been but partially examined. It is remarkable that an alloy of iron and nickel has been found in every meteoric stone hitherto examined.

Nickel possesses some valuable properties, but it is not found abundantly in nature, and its extreme infusibility will probably always prevent it from being much used in the arts.

* Tilloch's Magazine, xvi. 314.

DIVISION VI.

Metals which neither absorb oxygen, nor decompose water at any temperature ; and the oxides of which are reducible at a degree of heat below ignition.

In this division will be described the properties of Gold, Silver, Platinum, Palladium, Rhodium, Iridium, and we shall add Osmium.

SECTION I.

Of Gold.

DCLXIII. Gold has been known from the earliest ages. No other metal exhibits such a combination of valuable properties, and it was probably soon after its discovery adopted as a medium of exchange, or as a representative of property.

Gold is of a fine reddish yellow colour, and destitute of taste or odour. Its lustre is inferior only to that of steel and of silver, and it suffers no change on exposure to the air. In hardness it is inferior to some of the other metals, but it exceeds all but platinum in specific gravity ; its weight, compared with an equal bulk of water, being as 19.25 to 1, and when hammered as 19.35 to 1.

It is characterized by its malleability, ductility, tenacity, and unalterability on exposure to the air.

A grain of gold may be beaten so fine as to cover a space equal to 56 square inches. The common books of gold leaf contain only 4.8 grains ; hence it may be inferred, that the thickness of a single leaf is the $\frac{1}{282560}$ of an inch. An ounce of gold, covering a cylinder of silver, may be drawn into wire 444 French leagues in length ; and Dr. Black calculated that the thickness of a film of gold upon some silver wire which Reaumur had manufactured, bore the same proportion to one inch, as a single leaf of writing paper to $\frac{3}{4}$ of a mile. Gold leaf is diaphanous, and transmits a bluish green light.

Gold is equally ductile. By peculiar management Dr. Wollaston procured a wire so fine, that 550 feet of it weighed only one grain.

The tenacity of this metal is likewise very considerable, for a wire 0.078 of an inch in thickness will support a weight of 150.07 pounds.

On exposure to heat, this metal melts at 32° of Wedgewood, which is above 5000° of Fah. ; and while in fusion its surface exhibits a beautiful sea green colour. By cautious cooling it may be obtained crystallized in small 4-sided pyramids, or octaedra. In an intense heat, such as may be produced in the focus of the oxygen blow-pipe, it is dissipated in vapour, and both Macquer and Lavoisier succeeded by this method in gilding a silver plate.

Although compared with some of the other metals gold is of easy fusibility, there is none of this class which is less affected by an intense temperature. It has been exposed to the heat of a glass-house furnace for weeks without undergoing any change. Hence from this and experiments of a similar nature, it was once believed that it could not be oxidized by exposure to the air and to heat. It has however been reduced to a purple powder, both by the heat of a lens, and by electricity. When a leaf of this metal is enclosed between two plates of glass, and an electrical charge is sent through it, a portion disappears, and a purple substance is formed. Gold leaf, exposed to the action of a powerful voltaic battery, burns with a slight crackling noise, and with a brilliant yellowish light, and is converted into a powder, the colour of which is a mixture of purple and brown. Before the oxy-hydrogen blow-pipe, it likewise burns vividly and is oxidized. It may also be oxidized by deflagration with nitre.

Oxides of Gold.

DCLXIV. Of these there are two, the protoxide and the peroxide. Their composition has been particularly investigated by Oberkampft,* and by Berzelius.†

1. *Protoxide.* When the neutral muriate of gold is evaporated until it ceases to give out chlorine gas, and the residue is treated with solution of potash, a powder is produced, which constitutes the protoxide of gold. It is of a green colour, and decomposable by a degree of heat not much above ignition, oxygen gas is given out, and gold in its metallic state remains. It consists, according to the experiments of Berzelius, of 100 of metal and 4.026 of oxygen. Hence its composition may be thus stated ;

			Prop.						
Gold	-	-	1	-	-	100	-	-	96.13
Oxygen	-		1			4.026	-	-	3.87
			<hr/>						<hr/>
			2						100.00

The equivalent number of gold, therefore, is 186, and that of its protoxide $186 + 7.5 = 193.5$.

2. *Peroxide.* By dissolving gold in nitro-muriatic acid, evaporating cautiously to dryness, and heating the mass until it begins to give out chlorine, a muriate is formed, the solution of which yields with potash, on being heated, a precipitate which consists of peroxide of gold. When dried it is a reddish brown powder, insoluble in water, but soluble in muriatic acid, and decomposable by heat into oxygen gas and metallic gold. It is composed, according to Berzelius, of 100 of gold and 12.077 of oxygen; hence it appears to contain three times the quantity of oxygen that exists in the protoxide. It may be stated to be composed of

* Tilloch's Magazine, vol. xliv, p. 413.

† Annales de Chimie, t. lxxxiii, p. 166.

		Props					
Gold	-	1	-	-	100	-	89.225
Oxygen	-	3	-		12.077	-	10.775
		<hr/>					<hr/>
		4					100.000

and may be represented by $186 + 22.5 = 208.5$.

Gold in a state of minute division takes fire in chlorine gas, when aided by heat, and a brown deliquescent substance is formed. In a watery solution of chlorine, the metal, when in leaves, dissolves and forms a muriate.

Gold does not unite directly with sulphur, but an alkaline hydro-sulphuret separates from its muriatic solution a substance of a black colour, which has been regarded as a sulphuret. But when sulphuret of potash is melted with about $\frac{1}{8}$ its weight of gold, a compound is formed, which is soluble in water, giving to it a greenish yellow colour. Acids precipitate the gold in combination with sulphur. In this way Stahl explained the problem of the solution of the *Golden Calf* by Moses, and its conversion into a potable liquid, for the idolatrous Israelites.

The phosphuret of gold is white, brittle, fusible, and decomposable by heat. The solution of gold is decomposed by phosphuretted hydrogen; if it be not in excess metallic gold is precipitated; if in large proportion, the substance separated is a phosphuret.

Salts of Gold.

DCLXV. The strongest acids have no effect on metallic gold, and it may be immersed for an indefinite time in sulphuric, nitric, or muriatic acid without suffering any alteration. The proper, and indeed, only solvent of this metal, is nitro-muriatic acid. The proportion of nitric and muriatic acids, which produces the greatest effect upon this metal has been variously stated. M. Vauquelin affirms that 1 of the former to 2 of the latter answers best; Dr. Thomson mixes them in the proportion of 1 to 4.

Muriate of gold. Gold, assisted by a gentle heat, dissolves with a brisk effervescence in nitro-muriatic acid. The solution is of a fine yellow colour, and acid, and yields, by very cautious evaporation, small transparent crystals in the form of 4-sided prisms, or of truncated octoedrons, of a fine topaz yellow, very soluble in water and alcohol, deliquescent in the air, and of a bitter taste. When the solution is applied to the skin and to other substances the spot soon changes to a reddish purple, or amethystine colour, a change which is owing to the partial decomposition of the peroxide. Hence this solution constitutes one of the most effectual of the Indelible inks, as the colour or stain is permanent.

Muriate of gold is precipitated by the alkalies, but according to Vauquelin, it requires the liquid to be heated; the precipitate is of a red colour. If the alkali be added in excess, a portion of the oxide is redissolved. Even after potash has produced its full effect and the solution has become colourless, the addition of muriatic acid restores its yellow colour, and metallic gold is precipitated by green sulphate of iron. The alkalies do not, therefore, completely decompose the muriate; a portion of oxide still remains, and it is probably in triple combination, or a constituent of a triple compound.

The compound which results from the use of ammonia instead of the fixed alkalies, exhibits curious properties, and has been more thoroughly investigated by chemists. It constitutes *aurum fulminans*, or fulminating gold, the first known of all the metallic exploding compositions. It is prepared by diluting the neutral solution of gold with 4 or 5 times its bulk of pure water, and adding to it liquid ammonia so long as a precipitate continues to fall, or until there be a slight excess of ammonia. If more be added a portion of the precipitate will be redissolved. The whole is filtered through paper, the residue on the filtre is to be washed with large quantities of distilled water and allowed to dry without the application of heat. This substance explodes violently when heated to a temperature between 150° and 300° ; the same

effect takes place by friction, or percussion, and even by shaking the vessel in which it is contained. The report is sharp and always accompanied with light. When exploded in the quantity of 10 grains, it will lacerate and perforate a thin spoon of platina. Much caution is necessary in making experiments with it in any quantity, because the explosion is easily produced, and it is so violent as sometimes to occasion serious injuries to those who are careless or ignorant of its powers.

Fulminating gold has been proved to be a compound of ammonia and peroxide of the metal. The balance of affinities in it is so delicate, that a moderate increase of heat, and even a mechanical alteration of its parts, is sufficient to cause the elements of the ammonia and the peroxide to assume new arrangements. Both appear to be decomposed, the hydrogen of the ammonia combines with the oxygen of the oxide and forms water, the gold is reduced to its metallic state, and the azote assumes the elastic form; the impulse of the azote and the aqueous vapour upon the air, increased as it is by the high temperature, produces the explosion. According to Proust, 100 parts of fulminating gold produce by their decomposition 73 of pure gold.

The detonating power of this substance is much lessened by previously mixing it with any of the fixed alkalies or earths; and is destroyed by sulphur, and the fixed oils. It is not affected by diluted sulphuric or nitric acid, but it is decomposed by muriatic acid.

The attraction subsisting between gold and oxygen is so slight, that the muriate is decomposed by several of the combustible elements, particularly by hydrogen, carbon, and phosphorus, when exposed to light.

Scheele observed that the solution alone, when exposed for some days to solar light, exhibited minute spangles of gold.

A piece of silk or muslin dipped in the solution, then wetted with water, and exposed to a stream of hydrogen gas, becomes gilded. Charcoal, managed in the same way, and acted upon by light, becomes partly covered with reduced

gold ; and a stick of phosphorus immersed in a diluted solution, acquires a film of the metal upon its surface, which at length becomes so rigid, as to allow the phosphorus to be melted out, leaving the gold in the form of a tube. -

Muriate of gold is likewise decomposed by some of the metals and their salts. Zinc, copper, iron, and its green sulphate, precipitate gold in its metallic state ; silver, lead, tin, and its proto-muriate, in the form of protoxide. The purple powder of Cassius, which is used in colouring porcelain, is a compound of protoxide of gold, and peroxide of tin ; or of peroxide of tin with metallic gold. It is prepared either by immersing a plate of tin in a very diluted solution of muriate of gold ; or by adding to such solution proto-muriate of tin recently formed ; in either case a precipitate of a beautiful reddish purple colour is formed. If it be a compound of the two oxides, it is to be inferred that oxygen is transferred from the gold to the tin, the former is changed to a protoxide and the latter to a peroxide, both are rendered insoluble, and are precipitated in combination. If metallic gold be separated the tin must completely deoxidize it.

Nitric and sulphuric acids combine with the peroxide of gold, but the compounds possess no interesting properties.

Alloys of Gold.

DCLXVI. Most of these alloys have been examined with great care by Mr. Hatchett of London.* The alloy with iron is hard, of a yellowish gray colour, very ductile and malleable, and is stamped with ease without annealing. The proportion which gave these properties to gold was $\frac{1}{11}$ part of iron. Zinc even in small quantities is highly injurious to the ductility of gold. The alloy of 11 parts of gold to 1 of zinc is of a pale yellowish green colour and brittle. With manganese it becomes pale, brittle, and less fusible. Tin, in the

* Philosophical Transactions for 1803. Nicholson's Journal, vol. v. p. 286. 8vo.

proportion of $\frac{1}{10}$ rendered gold paler, and more brittle; in small quantities as $\frac{1}{80}$ it did not materially affect it. When gold is exposed to the vapour of metallic arsenic a combination readily takes place between them, and an alloy of a gray colour, brittle, and very fusible, is formed. When this compound is once made, it is difficult, from the strong affinity between them, to separate the arsenic. When the alloy contains only $\frac{1}{888}$ of arsenic, the gold retains its colour and becomes brittle. Minute quantities of antimony impair the brilliancy and destroy the ductility of gold; in larger proportions the compound has a pale, dull, unmetallic colour, and is exceedingly brittle. Cobalt, nickel, and bismuth debase the colour and injure the malleability of gold; this is particularly the case with the last, even when it constitutes only the $\frac{1}{2000}$ part of the alloy. Lead is nearly as injurious to gold as bismuth. Gold unites readily with copper and preserves its colour while it increases in hardness. When the alloy contained $\frac{1}{22}$ of copper it was of a fine yellow colour, with a tinge of red, and of a specific gravity equal to 17.159. The hardness of this alloy is said to be greatest when 7 parts of gold are combined with 1 of copper. Standard gold is pure gold, containing $\frac{1}{12}$ part of some other metal, which is either copper or silver, or a mixture of both, as in the coin of Great Britain.* The term *carat* is now applied to $\frac{1}{20}$ part of gold, and in the language of the mint, sterling gold is said to be 22 carats fine. Gold leaf contains copper, the purest 3 grains, and the coarsest 9 grains to the ounce, the medium quantity being 6 grains or $\frac{1}{80}$ part.

Gold and mercury have a strong affinity for each other, and they combine in any proportion, forming a perfectly white amalgam, which, when the excess of mercury is removed, is at first very soft, but gradually acquires firmness; it is very fusible, and when exposed to a temperature a little below ignition, is decomposed, the mercury passes off in va-

* Thomson's Chemistry, vol. i. p. 494.

pour and the gold remains behind. On this property is founded the art of gilding by an amalgam of gold.

The uses of gold are very numerous, and most of them probably are well known.

SECTION II.

Of Silver.

DCLXVII. Silver is one of the most beautiful of metals. By the alchemists it was compared to the moon, and was designated by the name of Luna, or Diana.

It is of a white colour with a very faint shade of yellow, susceptible of a polish inferior only to that of steel, and destitute of taste and odour. In hardness, elasticity, and sonorousness it is superior to gold, but inferior to that metal in malleability and ductility. Its specific gravity in its ordinary state is 10.47; but when hammered, 10.51. It is very malleable, and under the hammer may be reduced to leaves only $\frac{1}{180000}$ of an inch in thickness; and these leaves are impervious to the rays of light. A grain of this metal may be so extended, and at the same time possess so much firmness, as to form a cup capable of holding an ounce of water. Its ductility also is great, and it may be drawn into fine wire. Gold lace, as it is commonly called, is silver wire covered with a film of gold; six feet of it weigh only 1 grain, and when flattened between two cylinders, it is twisted around silk thread. In tenacity it is rather superior to gold, for a silver wire 0.078 of an inch in diameter will support a weight of 187 pounds.

Exposed to heat, silver melts at 22° of Wedgewood, about 3000° of Fah., its surface is very brilliant, and when the temperature is intense it boils and evaporates. By slow cooling it may be obtained crystallized in single or double 4-sided pyramids. It expands as it becomes solid.

Silver may remain for a long time exposed in its melted state to the air without suffering oxidizement. But it may

be burned by common and voltaic electricity. In the circuit of a strong voltaic battery silver leaf consumes with a beautiful and brilliant greenish white flame. It burns likewise in the flame of the oxy-hydrogen blow-pipe, and even on charcoal when urged by a stream of oxygen gas. In all these cases it is converted into an oxide of an olive colour.

Oxide of Silver.

DCLXVIII. There is but one well defined oxide of this metal. It may be obtained by decomposing the solution of silver in nitric acid by lime water, washing the precipitate, and drying it in a gentle heat. It is of a dark olive colour, insipid, insoluble in water, but soluble in the acids, and gives out oxygen when heated to ignition, and is completely reduced. According to Sir H. Davy, with whose experiments those of Berzelius and Dr. Thomson very nearly coincide, it consists of 100 of metal and 7.3 of oxygen. Hence its composition may be stated as follows.

		Prop.					
Silver	-	1	-	-	100	-	93.2
Oxygen	-	1	-	..	7.30	-	6.8
		<hr/>					<hr/>
		2					100.0

The equivalent number of silver will be 103 nearly, and that of its oxide 110.5.

Chloride of Silver.

DCLXIX. Silver, when heated in chlorine, does not inflame, but gradually absorbs it and forms a white solid, which, according to Berthollet's doctrine, is a dry muriate, according to Sir H. Davy's, a chloride of silver. It may be formed more expeditiously and in larger quantities, by pouring into a solution of nitrate of silver, liquid muriatic acid, or solution of common salt, a dense, curdy, and white precipitate is

separated, which is to be collected, washed with water, and dried in the shade. It is white, almost insoluble in water, blackens on exposure to the air, and fuses at about the temperature of 500° , producing on cooling, a gray, semi-transparent, tough substance, which, from its resemblance to horn, was called by the earlier chemists *luna cornea*, or horn silver. At a much higher heat it evaporates. It possesses the property, in common with the chlorides of some other metals, of absorbing ammoniacal gas; 30 grains, according to Mr. Farady, condense 40 cubic inches. It then becomes powdery, and inflames in chlorine gas. This chloride is soluble in liquid ammonia, and the solution deposits, after a time, transparent rhomboidal crystals, which appear to be a compound of ammonia and the chloride. Chloride of silver is decomposed and reduced by being heated with an alkali. The same effect is produced by some of the metals; and the first method may be employed, if sufficient care be taken, to obtain pure silver. Dr. Thomson states that the easiest way of procuring the silver from the chloride, is to boil it in an iron pot with water and pieces of iron. This compound has been analysed with great care by many eminent chemists. I consider the analyses of Dr. Marcet and Dr. J. Davy as probably approaching nearest the truth, for they both correspond exactly with its theoretical composition. Considered as a muriate, Dr. Marcet found it to consist of 19.05 of muriatic acid, and 80.95 of oxide of silver, which, when made to correspond with the proportion of the elements, if regarded as a chloride, will give 24.53 of chlorine and 75.47 of silver. We may, therefore, state its composition to be,

	Prop.	
Silver -	1 -	100 -
Chlorine -	1 -	32.52 -
	<hr/>	<hr/>
	2	100.00

And it may be represented by $103 + 33.5 = 136.5$.

From the insolubility of this chloride, the salts of silver are commonly employed as delicate tests of the presence of muriatic acid and its compounds.

The chloride of silver is acted upon by light, and in the violet ray of the prismatic spectrum is blackened in a few moments.

Silver combines with iodine and forms a greenish coloured substance, similar in some of its properties to the chloride.

Phosphuret of Silver.

DCLXX. This phosphuret is white, granular, soft, and brittle, easily decomposed by heat, and containing about $\frac{1}{2}$ its weight of phosphorus.

Sulphuret of Silver.

DCLXXI. Silver, on long exposure to the air, becomes tarnished, and its surface often presents an iridescent appearance. This is not owing to oxidizement, but as Proust found, to the formation of a sulphuret by the decomposition of sulphuretted hydrogen in the air, as it is formed most speedily in those situations in which that gas is usually extricated. The artificial sulphuret is of a deep violet colour, with some metallic lustre, opaque, brittle, and soft, more fusible than silver, and partially decomposed by heat. Sulphuretted hydrogen and alkaline sulphurets produce, in solutions of silver, a dark coloured precipitate; and metallic silver has its surface turned yellow by eggs, which are known to contain sulphuretted hydrogen. This sulphuret consists of 1 proportion each of its elements, and according to the experiments of Klaproth and Vanquelin, contains twice as much sulphur as there is oxygen in the oxide; or 100 of metal with 14.60 of sulphur. Its representative number is $103 + 15 = 118$.

Salts of Silver.

DCLXXII. *Chlorate of silver* crystallizes in rhomboids of little lustre or transparency, soluble in water and alcohol, and decomposable by many of the acids. It explodes violently by percussion with half its weight of sulphur. It is decomposed by heat alone, oxygen being evolved and the silver reduced.

Nitrate of silver. This metal decomposes nitric acid with facility, particularly if aided by a moderate heat. The solution, on cooling, deposits a portion of the salt in tables. If the acid have been diluted it remains in solution, which, when the silver has been pure, is colourless and transparent; if alloyed with copper, it becomes permanently blue; if with gold, the latter is precipitated in its metallic state; and if the acid contain chlorine or muriatic acid, a chloride is separated. This solution is dense, caustic, and deposits a dark coloured substance on exposure for a few days to light. The same effect is produced when it is applied to substances, and it has therefore been employed as an ink to stain hair, marble, &c. of a permanent brown. On evaporation it yields tabular crystals, which are white and so intensely bitter to the taste, that this salt has been called the *gall of metals*. The taste of the solution, though largely diluted, is metallic and nauseous.

Nitrate of silver is very soluble in water; and it is likewise dissolved by alcohol; it is permanent in the dark, but blackens and becomes opaque on exposure to light. When heated it melts, loses its water and it is said a portion of its acid, and becomes oily, in which state, when run into cylindrical moulds, it concretes, and is used in surgery by the names of *lapis infernalis*, and lunar caustic. Nitrate of silver may be decomposed by hydrogen gas, phosphorus, and charcoal, precisely like muriate of gold.

It explodes when struck forcibly in contact with phosphorus; and with $\frac{1}{3}$ of sulphur provided the hammer be heated.

It is decomposed by the alkalies, alkaline earths, and some of the metals. Ammonia throws down the oxide, which does

not possess any fulminating property ; but by an indirect method ammonia may be combined with it, and it then constitutes an explosive compound, more violent in its action, and more dangerous than the *aurum fulminans*.

It may be prepared by precipitating nitrate of silver by lime-water, the precipitate is collected and dried, and afterwards mixed with liquid ammonia; it assumes the appearance of a black powder, from which the liquid is to be decanted, and the solid allowed to dry in the air. The liquid, by gentle evaporation, deposits a crystallized substance, and both of them fulminate with prodigious violence, and from very slight causes ; so that motion, pressure, or mechanical alteration of parts produces instantaneous explosion. The greatest caution is not always sufficient to prevent this decomposition, and very serious injuries have been occasioned by it. The preparation is so dangerous that a few grains of it only should be made at a time and in an open vessel. This substance is a compound of oxide of silver and ammonia, and the theory of its detonation is the same as that of fulminating gold.

There are other methods, however, of producing an explosive compound from silver, which are safer than the one just described, and at the same time yield a substance capable of fulminating with great violence. Brugnatelli first prepared one of this kind by putting 100 grains of powdered lunar caustic into a flask, adding to it one ounce each of alcohol and strong nitrous acid, and applying a gentle heat, an effervescence took place, and a white ponderous powder formed, which, after the action had ceased, was collected and dried. When the action is violent, it should be lessened by the addition of distilled water. The process of Descotils also affords a good fulminating silver. It is essentially the same as that of Brugnatelli. It consists in dissolving silver in nitric acid, and adding, during the solution, about an equal bulk of alcohol, effervescence takes place, and a white powder is precipitated, which is to be collected, washed with dis-

tilled water, and dried. In both these cases the moist substance should be put in small parcels upon a piece or separate pieces of paper and dried in the shade, without heat. It possesses strong fulminating powers, and the explosion may be produced by heat, by friction, strong percussion, or by a drop of sulphuric acid. Two grains occasion a very loud report. Much care is requisite in preparing and performing experiments upon this substance, though its disposition to explosion is less than that of the ammoniated oxide.

The theory of its detonation is the same as that of fulminating mercury.

Silver is precipitated in its metallic state from its nitric solution by iron, copper, and mercury. If a little of the solution be spread upon a plate of glass, and a copper coin be immersed in the centre, it becomes surrounded with reduced silver, which continues to increase, and finally branches off in beautiful arborizations. A plate of copper in the solution is in a few minutes covered with a fleecy deposit of silver. Mercury introduced into it precipitates the silver in long and delicate needles. The experiment succeeds very well with a transparent solution of lunar caustic; the silver, as it separates, forms fine arborizations, which the older chemists designated by the name of *Arbor Dianæ*. The best effect, according to Homberg, is obtained by dissolving 4 parts of silver and 2 of mercury in nitric acid, diluting the solution with 48 parts of pure water, and adding to it a quantity of soft amalgam of silver. In a short time the shrub or tree will begin to shoot, and when the whole of the silver is precipitated it presents a beautiful arborization.

Pure silver may be obtained from the nitrate by the use of copper, and by digesting the precipitate in a weak solution of nitrate of silver, which dissolves all the copper but has no effect on the silver. This is Gay-Lussac's method.

Nitrate of silver is composed of 69 parts of oxide of silver and 31 of nitric acid.

Sulphate of silver. It may be formed by boiling sulphuric

acid on silver ; and adding diluted sulphuric acid. The salt obtained by evaporation is in fine prisms, white and brilliant, sparingly soluble in water, and soluble in nitric acid. It contains 1 proportion of sulphuric acid, and 1 of oxide of silver. It is decomposed by the alkalies &c. and by muriatic acid and its compounds. Hence it is often employed as a test of muriatic acid.

The other salts of this metal are for the most part insoluble, and are formed by double decompositions. The *arsenite* has been already described under the head of tests of arsenic.

Alloys of Silver.

DCLXXIII. Silver unites with many of the other metals. With iron, zinc, tin, arsenic, bismuth, cobalt, and lead, it forms alloys which are brittle, and for the most part white with shades of gray or blue. Its most important compound is with copper. They may be combined by fusion. The alloy is white, unless the copper predominate ; it is harder and more sonorous than silver ; and its specific gravity is below the mean of the two metals. Silver coin always contains copper, and the proportion in that of Great Britain is 1 of copper to $12\frac{1}{3}$ of silver ; or, as has been stated by others, 1 of the former to 15 of the latter.* This alloy is employed in plating. The amalgam of silver is white, solid, in dendritical crystals heavier than mercury. It is decomposed by heat. Silver and gold unite readily with each other by fusion, and form an alloy of a pale greenish yellow colour, harder, more sonorous, and more fusible than gold. The colour of gold is altered even by $\frac{1}{20}$ part of silver.

SECTION III.

Of Platinum.

DCLXXIV. No metal, perhaps, has been subjected to a more rigorous examination, and none has presented more un-

* Thomson's Chem. i. 480. 5th ed. Murray's Chem. iii. 315. 4th ed.

satisfactory results, than platinum. It was carried to Europe in the year 1741. The ore from which it is obtained is found only in South America and in Spain, and very complicated processes have been followed to procure from it the metal in a state of purity.

The colour of platinum is white with a shade of gray, inferior in lustre to silver and even to tin ; it is insipid, inodorous, of considerable hardness, and exceedingly ductile, malleable, and tenacious. It is the heaviest of bodies ; its specific gravity varying from 21.45 to 21.55. It is capable of being hammered into thin leaves, and it may be drawn into a wire hardly visible by the naked eye. Dr. Wollaston inclosed a wire in a cylinder of silver, passed the latter through the wire-drawing machine until it became very fine, and then dissolved the silver in nitric acid, leaving a filament of platinum only $\frac{1}{8000}$ of an inch in thickness ; he has even rendered it so attenuated as to measure only $\frac{1}{30000}$ of an inch in diameter. Its tenacity is likewise superior to that of silver, for a wire 0.078 of an inch in diameter will support a weight of 274 pounds.

Platinum, in common with iron, possesses the property of *welding*, and it is in this way alone that it can be fabricated ; for it is one of the most infusible of the metals, bearing without becoming liquid the strongest heat of a forge, and of a blast furnace. It is, however, fused in the circuit of a very powerful voltaic battery ; and melted with great ease in the flame of the oxy-hydrogen blow-pipe, and in that situation it throws off sparks of great brilliancy ; in fact it appears to undergo combustion.

Platinum suffers no change on exposure to air or to water.

It is made to combine with oxygen with great difficulty, independently of solution in an acid ; but Mr. Tennant found that the metal, when strongly heated with nitre, decomposed it and was oxidized, and this has been confirmed by Dobereiner. The only nitrates capable of producing this effect are those of potash and soda. Platinum is also oxidized by the action of electricity.

Oxides of Platinum.

DCLXXV. It has been found extremely difficult to determine the number of oxides of this metal and the proportions of their elements. This uncertainty has arisen partly from the circumstance that platinum cannot be combined directly with oxygen, and in part from the fact that the oxides of this metal are characterized by their disposition to form ternary compounds. Hence it has happened that Mr. E. Davy and M. Vauquelin have described but one oxide, while two have been assigned to platinum by Berzelius, Chenevix, and Mr. Cooper. The latter chemist, if he has not demonstrated, has certainly rendered probable the existence of two oxides, which I shall now describe.

1. *Protoxide.* It is procured by adding a neutral solution of mercury to a diluted solution of muriate of platinum in hot water, a precipitate takes place which is a mixture of calomel and oxide of platinum, and the former may be driven off by exposure to heat. This protoxide is black, and on exposure to strong heat gives off oxygen and leaves the platinum in its metallic state. It is likewise reduced by charcoal or lamp-black. From the experiments of Mr. Cooper it appears to consist of 100 of metal united with 4.423 of oxygen. The composition of this oxide may be thus stated.

	Prop.			
Platinum	-	1	-	100
Oxygen	-	1	-	4.442
		<hr/>		<hr/>
		2		100.00

Hence the equivalent number of platinum is 169.5, and that of the protoxide 177.

2. *Peroxide.* Berzelius obtained a dark brown oxide by the decomposition of the muriate of platinum by sulphuric acid, and adding to the sulphate caustic potash; 100 of the metal he found to be combined with 16.38 of oxygen. Mr. E. Davy states that fulminating platinum contains an oxide,

the elements of which exist in the ratio of 100 + 11.86. Vauquelin found them in the proportion of 85 + 15. If the peroxide be considered as a tritoxide, and from the difficulty of arriving at satisfactory results in these experiments, the supposition is allowable, the peroxide of platinum will consist of

		Prop.					
Platinum	-	1	-	-	100	-	88.25
Oxygen	-	3	-		13.326	-	11.75
		<hr/>					<hr/>
		4					100.00

And it will be represented by $169 + 22.5 = 191.5$.

This oxide is the basis of the salts of platinum. It is soluble in alkalies and their carbonates, combines with the alkaline earths, and forms triple compounds, particularly with ammonia and the acids.

Chloride of Platinum.

DCLXXVI. Platinum absorbs chlorine without inflammation and forms a compound, which, according to Mr. E. Davy, may be formed more easily by the decomposition of the muriate by heat. The chloride is of an olive brown colour, infusible, unalterable in the air, nearly insoluble in water, and in muriatic acid, and completely so in many other acids. It is decomposed by combustible bodies, particularly phosphorus and sulphur, which attract its chlorine. It consists, according to E. Davy, of 27.5 of chlorine and 72.5 of platinum. If it be considered as containing 2 proportions of chlorine, its theoretical composition will be

			Prop.					
Platinum	-	1	-	-	100	-	-	71.62
Chlorine	-	2	-		59.64	-		28.38
		<hr/>						<hr/>
		3						100.00

Its representative number will be $169 + 67 = 236$.

Mr. E. Davy has rendered it probable that there is a compound of 1 proportion each of these substances.

Phosphuret of Platinum.

DCLXXVII. Phosphorus combines with platinum in 2 proportions, forming a phosphuret and a bi-phosphuret.

1. When this metal and phosphorus are heated together in an exhausted tube, much light and heat are evolved, and a compound is formed of a bluish gray colour, fusible, of a metallic lustre, and capable of crystallizing in cubes. It consists, according to Mr. E. Davy, who first formed it, of 82.5 of platinum and 17.5 of phosphorus.

2. *Bi-phosphuret.* A compound of this kind was made by Pelletier, which was white, brittle, very hard, and fusible. Ed. Davy produced it of a dark colour, little metallic lustre, of a specific gravity of 5.28 ; it was unaffected by water or air, and was a non-conductor of electricity. He found it composed of 70 of platinum and 30 of phosphorus.

The composition of these phosphurets does not agree with that derived from calculation, supposing the number for phosphorus to be 20, unless the first contain 2, and the second 4 proportions of phosphorus.

Sulphurets of Platinum.

DCLXXVIII. Mr. Edmond Davy has described three sulphurets ; but his deuto-sulphuret has been lately formed by Vauquelin, who found it to correspond with the proto-sulphuret.

1. *Proto-sulphuret* may be formed, according to Vauquelin, by the action of sulphuret of soda on platinum, or by the transmission of sulphuretted hydrogen through a solution of platinum as neutral as possible ; a method practised by Mr. E. Davy. It is black, in brilliant needles, fusible in a close vessel, and indecomposable by the simple acids. Heated to redness in the open air, it loses, according to Vauquelin,

from 15 to 16.5 of sulphur, and platinum remains. Mr. E. Davy states its composition at $100 + 28.21$.

2. *Per-sulphuret*. It is prepared, according to Mr. E. Davy, by heating the triple muriate of platinum and ammonia with sulphur over mercury, and heating the product. It is nearly black, with a soft feel, little lustre, infusible in a strong heat, and a non-conductor of electricity. It is composed, according to the same chemist, of 100 metal + 38.8 of sulphur. Hence if we take Vauquelin's analysis of the proto-sulphuret as $84 + 16$, or $100 + 19.04$,[†] the sulphur in the per-sulphuret will be double that in the proto-sulphuret. But these do not agree with the number for platinum as deduced from the protoxide, and there is sufficient reason to believe that chemists are not yet well acquainted with the real oxides of this metal.

Salts of Platinum.

DCLXXIX. The only acid which has any effect upon platinum is the nitro-muriatic. When 16 parts of aqua regia, composed of 3 parts of muriatic to 1 of nitric acid, are poured upon 1 of platinum, and the mixture is exposed to a moderate heat, effervescence takes place, nitric oxide gas is disengaged, and a solution of a dark red colour is formed.

Muriate of platinum. This solution on evaporation yields small crystals of a reddish colour, of a disagreeable metallic taste, sparingly soluble in water, and decomposable by heat. Its concentrated solution has an acrid taste, and when applied to the skin produces a permanent stain of a brown colour. When evaporated to dryness, the chloride or bi-chloride of platinum is obtained according to the circumstances of the experiment as already detailed.

Soda does not decompose this solution, it merely heightens its colour; potash, on the contrary, renders it turbid and orange yellow; hence solution of muriate of platinum may, perhaps, be considered as one of the best means of distin-

guishing the two alkalies. The precipitate thrown down by potash is not a simple oxide of platinum ; if added in small quantity, a salt is soon deposited in the form of small octoedra crystals, of a reddish yellow colour, sparingly soluble in water, and constituting a triple compound of muriatic acid, peroxide of platinum, and potash. The salts of potash produce the same effect. In fact, all the alkalies combine with the muriate and form triple compounds. Hence there is an ammoniaco-muriate, which may be formed by adding a saturated solution of muriate of ammonia to muriate of platinum ; a yellow coloured precipitate takes place, which is the salt in question. If the ore of platinum have been employed, the precipitate, on a second addition of the sal-ammoniac, is orange red, and contains the oxides of some of the metals with which the platinum is associated. This precipitation by the muriate of ammonia is characteristic of the muriate of platinum. On exposure to heat the compound salt is decomposed and the platinum reduced.

Two compounds with soda may likewise be produced, the one formed by the action of muriate of soda, being in crystals of an orange red colour ; the other by caustic soda, in crystalline plates of a brownish red. The solution of the first occasions, with muriate of ammonia, a precipitate of a lively lemon colour, the second, with the same salt, a deposit of a yellowish green.

The solution of muriate of platinum is decomposed by several of the metallic salts ; the action of muriate of tin is very peculiar, and it may be considered as the best test of platinum. When recently made muriate of tin is employed, it immediately produces in the muriate of platinum a change of colour to a full red. This test is so delicate that a few drops of it added to 2 or 3 drops of muriate of platinum diluted with 2 ounces of water, give the whole a blood red colour.

Mr. Chenevix states the composition of the muriate of platinum when evaporated to dryness, at 70 of peroxide of platinum, and 30 of acid and water.

Sulphate of platinum. This salt may be obtained by the action of nitric acid on the proto-sulphuret of platinum; or by boiling insoluble muriate of this metal in sulphuric acid. It is in the form of a blackish mass, deliquescent, very soluble in water, alcohol, &c. and forms solutions of a yellowish green colour, on which muriate of ammonia has no effect, but from which a precipitate may be obtained after a time by the alkalies.

From this sulphate triple compounds may be formed of sulphuric acid, oxide of platinum, and the alkaline bases. According to Mr. E. Davy this simple salt is a compound of 73.7 oxide of platinum and 26.3 of acid.

DCLXXX. A compound which possessed strong fulminating properties was obtained by Mr. E. Davy from this sulphate. It may be prepared by adding to its solution ammonia in slight excess, the precipitate formed is to be moderately dried, and then boiled nearly to dryness in a strong solution of potash; after water has been added, the whole is to be filtered, and the residue, after being well washed, is to be dried at the temperature of boiling water. It is a brown powder specifically lighter than fulminating gold. It explodes violently at 400° ; but the explosion is not produced by friction or percussion. As it is a non-conductor of electricity, it does not detonate in the circuit of the voltaic battery. It is decomposed by chlorine and muriatic acid. When exploded, it produces ammonia, water, and azote. Mr. Davy considers it as a compound of 82.5 of oxide of platinum, 9 of ammonia, and 8.5 of water.

Alloys of Platinum.

DCLXXXI. Platinum combines with the other metals, but in general its alloys present few interesting properties.

The alloy of iron is formed with difficulty. With zinc, platinum produces a bluish white, hard, and brittle compound, and with tin, an alloy which is hard and brittle in proportion to the quantity of platinum. This metal forms a brittle compound with arsenic, which is decomposable by heat. A small proportion of platinum weakens the colour of copper ; in larger proportion, it forms an alloy which is hard and susceptible of a fine polish ; hence it has been used in the fabrication of mirrors for reflecting telescopes. It is both ductile and permanent in the air. Platinum forms with mercury a white amalgam ; and with silver an alloy which is harder and less ductile than that metal alone. A very small proportion of platinum alters the colour of gold, giving it a light gray appearance. The Spaniards prohibited the introduction of platinum into Europe from the fear that it might be employed in adulterating gold ; but their fears were groundless, for $\frac{1}{17}$ part of platinum debases the colour of gold so much as would readily lead to the discovery of the sophistication.

Uses of Platinum.

DCLXXXII. This metal exhibits a combination of valuable properties inferior only to gold. It is very hard, ductile, malleable, and scarcely acted upon by any other agents than nitro-muriatic acid, the nitrates, and alkalies. Hence it is adapted to a variety of purposes, particularly to the formation of chemical apparatus ; it expands less than any other metal, and hence was used by the French philosophers in the construction of their standard measure. It is said, also, to be better adapted than steel for the pendulum springs of watches. Its wire is very flexible, and may be employed with facility and advantage in many voltaic experiments. Some of its alloys form excellent specula. It has also been used to protect the surfaces of iron and copper from air and moisture. Platinum conducts heat more slowly than any other metal, excepting, perhaps, palladium. Hence it must

be employed in the nice experiments of Sir H. Davy on flame, and in the construction of the *lamp without flame*, as it has been called. It has also been introduced into the art of painting on porcelain by Klaproth. The only circumstances opposed to its general introduction into the arts, are the difficulty of obtaining it pure, and its extreme infusibility, so that all apparatus must be formed by welding.

The ore of this metal, to which the name of platinum is usually applied, appears in the form of small oval grains, of great specific gravity, very hard, and soluble only in nitro-muriatic acid. It has been sufficiently demonstrated that in this state it is far from being homogeneous, for besides iron, the researches of chemists have shown that it contains no less than 4 other metals, which are distinguished from each other by characteristic properties. Two of these were discovered by Mr. Tennant, and 2 by Dr. Wollaston. Their names are Iridium, Osmium, Rhodium, and Palladium.

SECTION IV.

Of Iridium.

DCLXXXIII. This metal was discovered in 1803, about the same time by Mr. Tennant of London, and M. Descotils of Paris.

In the ore of platinum there are found two kinds of grains, the one oval and of specific gravity equal to 17.5, the other white, flattened, and of a foliated structure, and 19.25 times heavier than water. After Mr. Tennant's discovery, Dr. Wollaston ascertained that the last consisted of the two metals iridium and osmium.

While the ore of platinum is dissolving in nitro-muriatic acid, there is deposited black and somewhat shining scales or powder, which, when heated to redness with an equal weight of potash, and dissolved in water, form an orange coloured solution. The residue, undissolved, is to be treated

with muriatic acid, which passes from blue to a deep red, and these processes are to be repeated until the whole has been dissolved. When the acid solution is evaporated to dryness, redissolved in water, and again evaporated, octoedral crystals of a fine red colour are obtained, which, after solution in water, are to be decomposed by a plate of zinc; oxide of iridium will be separated in flocculi of a black colour, and brilliant. This powder, when washed with water, and afterwards with water acidulated with muriatic acid, dried, and exposed to a gentle heat, becomes white and of a metallic lustre. Other processes have been given to separate iridium from the accompanying metals.

DCLXXXIV. Iridium is obtained with great difficulty in mass. Its fusing point appears to be as high as that of platinum; but Vauquelin procured a small quantity which was ductile. When iridium was exposed to Mr. Children's great voltaic battery, it melted into an imperfect globule exhibiting cavities; it was white, very brilliant, and of a specific gravity equal to 18.68.

Iridium combines with oxygen; but the combination is not powerful. It has been supposed to be susceptible of two degrees of oxidizement, the one blue and the other probably red, but nothing positive is known on this subject. It is not known whether it combines with the other supporters of combustion, or with the combustible bases, with the exception of sulphur.

The sulphuret, formed by mixing an equal weight of the ammoniaco-muriate of iridium with sulphur, and exposing them to a red heat, appears, according to Vauquelin, in the form of a black, agglutinated powder, composed of 100 of metal + 33.3 of sulphur.

None of the simple acids have any effect upon iridium, and it is dissolved with difficulty even by the nitro-muriatic. The solution is red; when concentrated it becomes deep blue, and again red when evaporated to dryness. The muriate may be obtained crystallized in octoedra of a red colour.

The oxide of iridium is soluble in the acids, forming green or blue solutions, which change to a red when diluted; or to a yellowish red on long boiling. Potash, when heated with iridium, oxidizes and combines with it, and produces a mass which is nearly black, but which becomes blue on solution in water.

Most of the metals decompose its muriatic solution, and precipitate iridium of a dark colour. Chlorine restores the original colour of the solution. Triple salts of iridium may be obtained by the medium of the fixed alkalies, and of ammonia. The salt with potash is purple or blue; with ammonia, deep purple, which changes to an orange red when dissolved in water. It was from the great variety of colours displayed by the compounds of this metal, that Mr. Tennant gave it the name of Iridium.

Iridium forms alloys with some of the other metals, but they have not been extensively examined.

SECTION V.

Of Osmium.

DCLXXXV. It was remarked in the account of iridium, that the black powder remaining after the action of nitro-muriatic acid upon the ore of platinum, was dissolved by the alternate operations of an alkali, and of muriatic acid. The acid solution contains iridium, and the alkaline solution, an oxide of a peculiar metal, which, from one of its characteristic properties, its strong smell, was called by Mr. Tennant *Osmium*.

The oxide may be obtained from this liquid by mixing sulphuric acid with it and distilling by a gentle heat. The oxide being volatile, passes over with the aqueous vapour, and forms a colourless solution of a sweetish taste, and of a peculiar, somewhat irritating odour. Another method by which the oxide may be obtained in a more concentrated

state, consists in distilling the black powder with nitre, at a low red heat. A sublimate of an oily appearance is formed, which, on cooling, concretes into a solid mass, semi-transparent, destitute of colour, and soluble in water, to which it gives the peculiar odour of oxide of osmium.

Osmium itself appears to be unalterable by heat, but its oxide rises in vapour at a very moderate temperature. The oxide on solution in water may be decomposed by agitating it with mercury, and the two metals may be separated by straining the amalgam through leather, and distilling off the mercury which still adheres to it in a close vessel.

Osmium obtained in this way is a powder of a dark gray or bluish colour, and having some metallic lustre. It undergoes no change when heated to whiteness out of contact with the air, but if this precaution be not taken, it becomes oxidized, and the oxide speedily evaporates, sending forth its characteristic odour.

The proportion in which it combines with oxygen is unknown. Vauquelin obtained an oxide by sublimation, in the form of brilliant white crystals, of a very sharp taste, and intolerably pungent odour, very fusible and volatile, and capable of staining the skin of a deep brown or black colour.

Osmium is easily deoxidized by a number of the metals; likewise by alcohol and ether. It combines only with muriatic acid; there is no acid, not even nitro-muriatic, which will operate on osmium in its metallic state. The solution in muriatic acid is at first green, then reddish yellow. It is decomposed by infusion of galls which gives a deep blue colour.

Chlorine acts upon osmium, causes it to assume a fine green colour, and finally converting it into a brownish red liquid, which is decomposed by galls, by potash, and by some of the metals.

Very little is known of the alloys of osmium.

Osmium and its oxide are distinguished by several very curious properties. Though it is the least acted upon by the acids of any of the metals, yet it is oxidized with the great-

est facility by heat and air. Its oxide is volatile at a low heat, has a peculiar odour, and a sweetish taste, is soluble in water, and combines more easily with alkalies than with acids.

SECTION VI.

Of Rhodium.

DCLXXXVI. This is the third of the metals associated with native platinum. It was discovered in 1804 by Dr. Wollaston, and from the rose colour of some of its solutions was named by him Rhodium.

It is obtained from the ore of platinum by a tedious and complicated process.* Its properties have been since examined by Descotils,† Berzelius,‡ and Vauquelin.§

Rhodium is white, brittle, of a granulated texture, very hard, and of a specific gravity equal to about 11. It is one of the most infusible of the metals, it being but imperfectly melted in the intense heat excited by a stream of oxygen gas on ignited charcoal.

Oxides of Rhodium.

DCLXXXVII. According to Berzelius, rhodium is capable of combining with three definite proportions of oxygen, and of forming 3 oxides.

1. *Protoxide.* It may be obtained by reducing the metal to powder, and exposing it in an open vessel to a moderate red heat; the metal absorbs oxygen, becomes black, but is destitute of metallic brilliancy, and when slightly heated with tallow or sugar, is decomposed with detonation. It is insoluble in acids when thus procured. From the experiments of Berzelius, it consists of 100 of metal combined with 6.71 of oxygen; hence its constitution may be thus expressed;

* Philosophical Transactions for 1804, p. 422.

† Journal de Physique, lxi. p. 399.

‡ Annals of Philosophy, vol. iii. p. 252.

§ Tilloch's Magazine, vol. xlv. p. 33.

		Prop.					
Rhodium	-	1	-	-	100	-	93.712
Oxygen	-	1	-		6.71	-	6.288
		<hr/>					<hr/>
		2					100.000

The equivalent number of rhodium, therefore, will be 111.7 and that of the protoxide 119.2.

2. *Deutoxide*. This compound, procured by treating rhodium in powder with caustic potash and a little nitre, and lixiviating the mass, is light, puce coloured, capable of forming compounds with the alkalies, and of being precipitated from them by the acids. It contains, according to Berzelius, between 15 and 16 per cent. of oxygen. If it be a deutoxide, it has double the quantity of oxygen which exists in the protoxide; and from the difficulty of experimenting accurately upon very small quantities of this metal, we may reject the excess of oxygen in Berzelius' estimate, which prevents the numbers from being in definite proportions to each other. In this case the deutoxide will be composed of

		Prop.					
Rhodium	-	1	-	-	100	-	88.17
Oxygen	-	2	-		13.42	-	11.83
		<hr/>					<hr/>
		3					100.00

and its equivalent number will be $111.7 + 15 = 126.7$.

3. *Peroxide of rhodium* is obtained by precipitating sodamuriate of rhodium by caustic potash, a reddish substance, the hydrated peroxide, is separated, which, when exposed to heat, loses its water, becomes darker coloured, and heated to below redness takes fire, gives off oxygen, and is reduced to the state of protoxide. Berzelius explains this combustion upon the hypothesis, that when the peroxide loses a portion of its oxygen, the remainder forms a more intimate combination with the rhodium.* This peroxide consists apparently of

* Annals of Philosophy, vol. iii. p. 256.

	Prop.					
Rhodium	- 1	-	-	100	-	85.25
Oxygen	- 3	-		20.13	-	16.75
						<hr/>
	4					100.00

Its representative number will amount to $111.7 + 22.5 = 134.2$.

DCLXXXVIII. Rhodium may be combined with sulphur by heating the latter with the ammoniaco-muriate of the former. It is of a bluish colour, fusible, and decomposed by being heated in contact with the air. Vauquelin states it to contain about 26 per cent. of sulphur. This might lead us to infer that it is a bi-sulphuret.

Salts of Rhodium.

DCLXXXIX. Metallic rhodium is not acted upon by any acid, but the deutoxide combines with this class of bodies and forms salts. Rhodium like platinum and iridium is distinguished by its property of forming triple compounds. The solutions of these salts in water are red; they are not decomposed by triple prussiate, or ferruretted chyazate of potash, hydro-sulphuret of potash, muriate of ammonia, nor the alkaline carbonates; but the caustic alkalies precipitate a yellow powder.

Rhodium unites with many of the metals, but does not amalgamate with mercury.

SECTION VII.

Of Palladium.

DCXC. This is the last and the best known of the metals associated with platinum. It was discovered in 1803 by Dr. Wollaston; and in an elaborate suite of experiments, Mr. Chenevix endeavoured to show that it was an amalgam of

platinum and mercury.* He succeeded in forming a compound exhibiting properties in some degree similar to those of palladium, but the knowledge of the discoverer of that metal, and the subsequent experiments of chemists, confirmed the opinion of Dr. Wollaston.

The easiest method of obtaining palladium is to add solution of cyanide of mercury to solution of the ore of platinum in nitro muriatic acid, a yellowish white precipitate takes place, which, when heated strongly, produces pure palladium, and when subsequently heated with sulphur and borax, it may be obtained in mass.

DCXCI. It has a close resemblance to platinum, but is whiter ; it is susceptible of a good polish, is ductile, and malleable, so that it may be beaten or rolled into thin slips, but is not very elastic ; its texture is fibrous and apparently crystallized, its hardness is superior to that of iron, and its specific gravity varies from 10.9 to 11.8.

It is hardly fusible in a furnace, but melts on charcoal before the oxygen blow-pipe, and undergoes combustion, throwing off brilliant sparks. Palladium, next to platinum, is the worst conductor of heat among the metals.

Oxide of Palladium.

DCXCII. When exposed to air and heat the surface of palladium assumes a blue colour, which disappears on increasing the heat, the lustre of the metal being restored. It is not oxidized, therefore, permanently in this way. According to Berzelius, an oxide may be formed by heating the metal in filings with potash and nitre, a chesnut coloured substance is obtained, which may be dissolved in muriatic acid, and which consists of 100 of palladium combined with 14.209 of oxygen. It is the only oxide of this metal.† If it contain but 1 proportion of each of its elements, its composition may be stated as follows ;

* Nicholson's Journal, vol. xi. p. 162.

† Annals of Philosophy, iii. 354.

	Prop.					
Palladium	- 1	-	-	100	-	87.56
Oxygen	- 1	-		14.209	-	12.44
						<hr/>
	2					100.00

Hence the equivalent number of palladium is about 53 and that of its oxide 60.5.

Sulphuret of Palladium.

DCXCIII. This compound may be obtained by exposing palladium, or its ammoniaco-muriate, to heat with sulphur. Even when red hot, if palladium be touched with sulphur, a sulphuret is immediately formed, which runs into a liquid. This compound is white, brittle, fusible, and decomposable by a strong heat.

Salts of Palladium.

DCXCIV. Nitric acid acquires a red colour when digested with palladium, but no gas is given out. The action of fuming nitric acid is more energetic, the solution is of a fine red colour, and by evaporation yields a substance of a dark red.

It forms a red solution with nitro-muriatic acid, and with sulphuric acid. These are decomposed by the alkalies, an orange coloured precipitate being formed, which is in part redissolved when the alkali is in excess.

The oxide of palladium, likewise, produces triple compounds with the alkalies and acids.

From its solution in acids, ferruretted chyzate of potash occasions an olive coloured precipitate; solution of sulphuretted hydrogen a dark brown; prussiate of mercury throws down a yellowish white substance; and metallic palladium is precipitated by green sulphate of iron. All the metals, excepting those of the last division, precipitate palladium in its metallic state.

The alkalies, and particularly potash, act upon this metal in the same way as on platinum.

Palladium may be combined with several of the other metals. It debases the colour and diminishes the specific gravity and ductility of gold. Its alloy with silver is hard, white, and heavy. It gives to copper a tinge of yellow, and renders it hard and brittle. Its compound with lead is very hard and brittle, but more fusible than palladium, and of a specific gravity equal to 12.00. It also combines with, without altering in an essential degree the properties of, platinum. It also unites with iron, tin, bismuth, and arsenic.



Of Cadmium.

DCXCV. The existence of another metal, to which has been applied the name of *Cadmium*, has been sufficiently demonstrated by Stromeyer and Gay-Lussac.* From the properties it exhibits, Cadmium should be placed in the *Third Division* of the metals, immediately after zinc. Stromeyer's account of it, however, was not received in time to allow of this arrangement.

Cadmium was obtained in the autumn of 1817 by Stromeyer from a carbonate of zinc, which exhibited a dazzling whiteness, but it became yellow on exposure to a red heat. This colour he found to be owing to the presence of a peculiar oxide, which existed in the proportion of from $\frac{1}{1000}$ to $\frac{1}{100}$ part of the whole mass, and which, on being reduced, afforded a metallic base with the following properties.

DCXCVI. It has a white colour, intermediate between that of tin and platinum; it is brilliant, is susceptible of a fine polish, has a compact texture, and hackly fracture, and a specific gravity, after having been melted, equal to 8.750. It is very ductile and malleable, and may be beaten into thin

* Annals of Philosophy, vols xii. p. 152 and xiii. p. 108.

plates, both cold and hot, without cracking. In thin sheets it produces, when bent, the peculiar crackling noise which has been thought characteristic of tin. It is fusible, and may be melted and volatilized at a temperature below a red heat; its vapour is destitute of odour, and congeals like mercury in drops, which exhibit distinct traces of crystallization.

It suffers no change on exposure to the air, but when heated it burns very readily, and is converted into a yellow coloured oxide, the greater part of which sublimes in the form of yellow vapour. Before the blow-pipe it covers the charcoal with a brownish yellow coat. This oxide has no smell; it gives no colour to borax; it dissolves in the acids, and forms colourless salts, from which it is precipitated white by the alkalies. There is but one oxide of cadmium. It is infusible in the strongest heat, but in contact with carbonaceous matter it is decomposed at a very low degree of ignition.

Oxide of cadmium is insoluble in solutions of the fixed alkalies, but a portion of it is taken up by ammonia. It acts towards the acids the part of a salifiable base. Its sulphate, nitrate, muriate, and acetate, crystallize readily and are very soluble; but the salts formed with phosphoric, carbonic, and oxalic acids, are insoluble in water. The alkalies precipitate it in the form of white hydrate; by ammonia it is first precipitated, and if the former be added in excess, is redissolved. The same effect is produced by liquid carbonate of ammonia. When the solution is exposed to the air, the carbonate very speedily precipitates again. We may, therefore, says Stromeyer, employ carbonate of ammonia with advantage to separate this metal from zinc and copper when it is mixed with them. From its solutions, prussiate of potash throws it down *white*, sulphuretted hydrogen and the hydro-sulphurets *yellow*, in appearance like the golden sulphur of antimony, or in some cases, like orpiment, or yellow sulphuret of arsenic. It is separated in its metallic state by zinc, but it precipitates copper, lead, silver, and

gold from their solutions. Its compounds with iodine, sulphur, phosphorus, and the other metals, have not been examined; but it combines by heat with platinum; and forms a solid, crystallizable amalgam with mercury.

Of Vestium.

DCXCVII. In August 1818 Professor Vest of Gratz announced the existence of a new metal in an ore of nickel from Schlading in Upper Steiermark. This ore, besides nickel, contained cobalt pyrites, and arsenic. It was found extremely difficult to free vestium from the metals with which it was associated, but Mr. Vest supposed that he had succeeded in separating them. Its properties are very similar to those of nickel and cobalt. Its oxide is soluble in the acids and forms with them colourless solutions, which, on evaporation, yield the salt in the form of a crust or of fine needles. When redissolved and allowed to be at rest, they separate from the solution in white flocks. Prussiate of potash precipitates oxide of vestium in milk-white flocks; and sulphuretted hydrogen produces a precipitate of a *reddish brown* colour, soluble, with effervescence, in nitric acid. Phosphate of soda and oxalate of potash occasion a white precipitate. A plate of zinc, left for some days in a solution of vestium, throws down white flocks. Dr. Vest thinks that this metal combines with two proportions of oxygen.

Of Wodanium.

DCXCVIII. Lampadius has lately discovered a new metal, to which he has given the name of Wodanium. It was found in a mineral from Tospeschau in Hungary, which, besides this metal, contained sulphur, arsenic, iron, and nickel.

Wodanium is a metal of a bronze yellow colour, of a hackly fracture, of a degree of hardness equal to that of fluor spar, malleable, and of a specific gravity of 11.470. It is strongly attracted by the magnet. At common temperatures it is not altered on exposure to the air, but when heated it is converted into a black oxide. It is dissolved in the acids, forming solutions, which have, at most, a slight wine yellow tinge. Its hydrated carbonate is white. The hydrate of this metal precipitated by ammonia is indigo blue. Neither the alkaline phosphates nor arseniates occasion any precipitate when dropped into a saturated solution of the metal in an acid; nor is any precipitate produced by infusion of galls. A plate of zinc throws down a black metallic powder from the solution of this metal in muriatic acid. From prussiate of potash the precipitate is pearl gray. Nitric acid dissolves both the metal and its oxide with facility, and the solution yields colourless needle-formed crystals, which readily dissolve in water.

The name of this metal is derived from Woden or Wodan, a deity of the ancient German Mythology.

DIVISION II.

OF ORGANIC BODIES AND THEIR PRODUCTS.

DCXCIX. **T**HE bodies now to be described differ in several essential points from those of which the chemical history has already been given. As a class they are distinguished from inorganic matter,

1. By irritability, or the susceptibility to contraction by the application of stimuli.
2. By the power of appropriation or assimilation.
3. By the power of reproduction or of continuing the species.

The products of the operation of the vital powers on matter differ likewise from those which are the results of mechanical action, in the greater number of elements composing them, in the proportions in which they unite, and in the delicate balance of affinities which they exhibit. Hence it happens that compounds formed by organic bodies are less permanent than those which take place in unorganized matter, and that when uncontrolled by the laws of life, they undergo a series of spontaneous changes, and their elements unite in proportions like those which may be easily imitated by the chemist. The proportions in which the elements of organic bodies combine, though they may be definite, are more numerous than can be produced by art; and, in some instances, where they are the same, bodies of different properties have been formed, from a difference either in the condensation of their elements, or the arrangement of their particles. Many of these products consist, for the most part, of substances which may be readily recognized by reagents;

but the character of each is derived from the presence of a peculiar substance, the nature of which is not understood. This is the case with many of the animal fluids, and has been particularly pointed out by Berzelius. There are certain compounds which are common to the two great classes of organic and inorganic matter, such, for example, as some of the salts, and these may be produced by the chemist without difficulty ; but in analyzing an animal or vegetable product he must either expose it to heat, by which it is reduced to its ultimate elements, carbon, oxygen, hydrogen, &c. or to their binary compounds ; or to the action of various solvents, which do little more than separate its proximate elements or principles, which are still compounded. Thus, though he may be able to state the nature and proportion of simple bodies of which it is composed, yet the demonstration of its composition is imperfect, for he cannot recombine them in a way to form anew the product with the same physical and chemical properties. These circumstances distinctly characterize the class of bodies which is now to be described. For it is questionable whether the chemist has ever combined the elementary bodies in such number and proportion as to form a compound similar in every respect to any one which is a peculiar product of an organic system.

That a series of chemical actions is continually going on in the systems of vegetables and of animals is evident ; but the laws of chemistry at the same time appear to be subordinate to the vital powers, and the former are exalted or depressed, modified or controlled by the latter, according to the circumstances in which those systems are placed. Modern physiologists, in establishing the principles of their science, have derived much assistance from the researches and discoveries of the chemist, but many of the deductions flowing from them have been premature, and no permanent theory can be established until observation and experiment have developed the relations which subsist between the laws regulating common matter, and the powers which govern organized and living systems.

DCC. The subjects of the following pages admit of a natural and appropriate division into those which are of vegetable, and those which are of animal origin. The structure of plants is apparently more simple than that of animals, their organs are fewer in number, their functions are less complicated, and their products, for the most part, less compounded. They will therefore be first described.

BOOK I.

Of the Structure, Chemical Products, and Spontaneous Decomposition of Vegetables.

DCCI. The chemical history of the bodies, included in this division, may be considered under three heads ; first, the properties of the substances of which vegetable matter is composed ; secondly, the structure and functions of plants ; and thirdly, their spontaneous decompositions and the products resulting from new combinations of their ultimate elements.

CHAPTER I.

OF THE PROXIMATE PRINCIPLES OF PLANTS.

DCCII. In the examination of vegetable bodies a number of distinct and characteristic substances have been discovered, which, though not simple, may be regarded as their elements. To these has been given the name of *proximate principles*. They are not all present in the same plant, but there is no individual of this division which is not composed of a greater or less number. The basis of these proximate elements is carbon, the properties of which are more or less modified by its combination in various, but probably, definite proportions, with oxygen, hydrogen, azote, &c. It does not appear that a simple binary compound of these elements can be found in the vegetable system, at least in reference to the proximate principles. The greatest number of them is composed of carbon,

oxygen, and hydrogen ; and the remainder are quaternary compounds, containing nitrogen or azote. The substances which are found in vegetables, and which are common to organic and inorganic matter, are some of the salts and metallic oxides.

DCCIII. The following bodies may be ranked among the ternary compounds.

Gum	Resin
Fecula	Tannin
Jelly	Ulmia
Sugar	Emetin
Wax	Lignin
Oil	Colouring matter
Camphor	Morphia
Acids.	

Among the quaternary compounds may be ranked

Gluten	Bird-lime
Albumen	Indigo
Caoutchouc	Asparagin
Extract.	

The ternary compounds will be first described.

SECTION I.

Of Gum.

DCCIV. Gum, either in the solid or liquid form, in the last of which it is called *mucilage*, exists in the seeds and roots or substance of some plants, and is thrown out by exudation from the surface of others where it concretes. It may be obtained with facility in the form of mucilage by decoction or maceration from flax seed, the root of the marsh-mallow, and from the substance of some of the mosses. The solid gum of commerce is the product of the *Mimosa Nilotica*, and the *Astragalus Tragacantha*, and is familiarly known by the names of Gum Arabic, and Gum Tragacanth.

It is usually in the form of small fragments, hard, brittle, semi-transparent, with a tinge of yellow or red ; but when perfectly pure is white. It is inodorous, insipid to the taste, but adhesive, infusible, and almost incombustible, though decomposable with facility at a high temperature. It suffers no change on exposure to the air, but becomes white by the influence of light.

DCCV. Gum is extremely soluble in water, being dissolved by it in any quantity ; the solution which is called mucilage is viscid, glutinous, and adhesive, and when spread in thin films upon a surface exposed to the air, it soon dries and has the polish of the varnishes. But it is apt to attract moisture and become soft and glutinous. The gum may be obtained from it by evaporation, in a solid state, unchanged in its properties. This liquid may be preserved for a long time, and perhaps no vegetable product is less disposed to spontaneous changes. After a while, however, it produces vinegar. It is incapable apparently of fermenting. When added to the acids it is decomposed, and the products differ according to the acid employed. With nitric acid the results are oxalic, saccho-lactic, and malic acids ; muriatic acid partly decomposes and in part dissolves it ; and by sulphuric acid it is converted into charcoal, acid of vinegar, and water.

According to Vauquelin chlorine acts upon solution of gum, and forms citric acid. Gum is soluble in the caustic alkalies and precipitated from them by the acids.

It is separated from its solution by silicated potash in the form of a white flaky deposit, though very much diluted ; and this compound is considered by Dr. Thomson as by far the most delicate test of the presence of gum. According to the same chemist solution of per-muriate of iron, when concentrated, converts a very strong solution of gum into a brown semi-transparent jelly, which is not readily dissolved in water.

Gum is insoluble in alcohol, or strong spirits of wine, and when the latter is added to solution of the former, and the

two liquids are mingled, the whole becomes turbid and opaque, the gum being separated.

DCCVI. On exposure to heat the substance of gum softens and swells up, but does not become liquid. It then grows black, emits air bubbles, and, when nearly reduced to charcoal, takes fire, burning with a low blue flame. By destructive distillation in close vessels it yields water, vinegar, empyreumatic oil, carbonic acid, and carburetted hydrogen gases, charcoal, lime, and phosphate of lime. Hence it has been inferred to consist essentially of carbon, oxygen, and hydrogen. The same conclusion has been drawn by M. M. Gay-Lussac and Thenard, who analyzed this principle by burning it in contact with chlorate of potash. The following are the proportions of the elements of gum, as stated by different chemists.

Carbon	23.08*	42.23†	41.906‡	45.84§	} Nitrogen 0.44.
Hydrogen	11.54	6.93	6.788	5.46	
Oxygen	65.38	50.84	51.306	48.26	
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.000	<hr/> 99.56	

Besides these, gum may be proved to contain lime, but whether it be essential or adventitious does not appear to be decided. When chlorine is made to act upon solution of gum the citric acid formed is found to be combined with lime; and if a few drops of sulphuric acid be added to mucilage, and the liquid be set aside for some weeks, sulphate of lime in acicular crystals will be deposited.

DCCVII. The gum of the *Astragalus Tragicantha* differs in some respects from that of the *Mimosa Nilotica*. It is in the form of whitish, wrinkled, vermiform pieces, neither so transparent nor so beautifully coloured as gum arabic. It is less easily dissolved in water, and its solution is more ad-

* Fourcroy and Vauquelin.

† Gay-Lussac and Thenard—*Recherches*, t. ii. p. 290.

‡ Berzelius—*Annals of Philosophy*, v. 270.

§ Saussure—*Annals of Philosophy*, vii. 46.

hesive. In the arts it is known by the name of gum Adraganth, or gum Dragon.

Senegal gum is of a deeper colour, and in larger masses than gum arabic, but is similar to it in chemical properties. The former is often substituted in the shops for the latter, and it is more commonly used in the art of calico-printing.

Many of the fruit trees in our gardens likewise produce gum, which is analogous in its properties to those just described, such as the plum, cherry, apricot, and almond. It is of a reddish brown colour, in large masses, much softer, and more easily melted than the imported gums.

Mucilage is found in considerable proportion in the different species of lichen, in the roots of the hare-bell and mallows, in the bark of the *slippery elm*, and in the seeds of several plants.

DCCVIII. Gum and mucilage are employed in large quantities in some of the arts, particularly in calico-printing, in which it answers the purpose of increasing the consistency of the colours, and preventing them from spreading on the cloth. It is also used by the dyer; and it enters into the composition of writing ink. In pharmacy it is made the medium of union between other substances.

Gum is a nutritious substance, and the mucilage from the Iceland moss has been celebrated in cases of pulmonary consumption. It is related, that in some instances, persons who have composed the caravans passing from Arabia over the deserts to Egypt, have preserved their lives for many days by the eating of Senegal gum, with which their camels were partly loaded, after all other provision was exhausted.

SECTION II.

Of Farina, Fecula, or Starch.

DCCIX. This is one of the most important of the proximate principles of plants. It constitutes the basis of the farinaceous grains, and is the chief source of nourishment

drawn from the vegetable kingdom. It appears to be perfectly formed only at certain periods of the growth of these plants, and the observations of Leronx favour the opinion, that it arises from changes particularly in the mucilage.

Starch may be obtained from wheat flour by making it into a paste with cold water, and kneading it for some time under the surface, or exposing it to a stream of that liquid. The water becomes milky, and on standing deposits a fine white powder, which is to be collected and dried. For the purposes of commerce, it is procured from grains of wheat by steeping them in water until the husk is separated; they are afterwards enclosed in hempen bags and subjected to pressure, by which a milky liquid is pressed out; cold water is poured upon the bags, and the process is repeated until the grains cease to afford the white emulsion. When allowed to stand, there is gradually deposited a white powder, which, when collected and dried, breaks into columnar masses of Farina or Starch.* The water which had stood over starch was found by Vauquelin to contain alcohol, vinegar, phosphate of lime, and ammonia. The wheat contains sugar, which, when dissolved in the liquid, undergoes acetous fermentation, and the presence of acid matter, it is said, gives to the starch a finer white.

DCCX. Farina is white with a shade of blue; insipid, inodorous, insoluble in cold water, and unalterable in dry air.

When a mass of starch is immersed in water at the common temperature of the air, it gradually falls into powder, and when agitated forms with it an emulsion or milk-like fluid, from which it is precipitated unaltered on standing at rest. If this emulsion be heated to about 160° , a solution is formed, which is thick, glutinous, and opal coloured, and on cooling is converted into a soft tremulous jelly. When evaporated to dryness the starch is obtained in the form of a dry and nearly opaque mass.

DCCXI. When heated in contact with the air, starch apparently melts, the mass increases in bulk, charcoal is disen-

* Aiken's Chemical Dictionary, *article* Starch.

gaged, and at length active combustion takes place. Distilled in close vessels, it yields vinegar, empyreumatic oil, carbonic acid, and carburetted hydrogen gases, and charcoal. Hence its ultimate elements may be inferred to consist of carbon, oxygen, and hydrogen. The following are the proportions as assigned by different chemists.

Carbon	-	43.55*	-	43.481†	45.39‡	} Azote 0.40.
Oxygen	-	49.68	-	49.455	48.31	
Hydrogen		6.77	-	7.066	5.90	
		<hr/>		<hr/>	<hr/>	
		100.00		100.00	99.60	

The analysis by the French chemists gives very nearly the same proportions as those which exist in gum arabic, and in fact a considerable analogy appears to exist between these two principles. It has been proved both by La Grange and Dobereiner that by gently roasting starch, it may be rendered soluble in cold water, and thus be made to approximate to gum.

DCCXII. When starch is triturated with iodine, a compound is formed, which exhibits a beautiful indigo-blue colour, which is so intense, and produced by so small a quantity of farina, that this principle may be considered as the most delicate test of the presence of iodine. It is affirmed by Stromeyer that it assumes a perceptibly blue tinge when the iodine exists in no larger proportion than $\frac{1}{430000}$ part. But, as remarked by Gaultier de Claubry and Stromeyer, the iodine must be uncombined, for starch will not detect it in the form of oxiodic or hydriodic acid. These acids must be previously decomposed and the iodine separated by means of some other acid. The iodide of starch may be obtained by triturating starch with an excess of iodine, dissolving the mass in solution of potash, and precipitating the compound by the addition of an acid.

* Gay-Lussac and Thenard—Recherches, t. ii. p. 292.

† Annals of Philosophy, vol. v. p. 273. ‡ Ibid, vol. vi. p. 427.

The action of the simple inflammable substances on starch has not been investigated.

DCCXIII. It is either dissolved or decomposed by the acids. When concentrated sulphuric acid is added to dry starch, the mass becomes black, and of thick consistence. With diluted acid the actions are different, and by peculiar management, as discovered by Kirchoff, sugar may be obtained as one of the products.

Nitric acid dissolves a portion of starch, forming a greenish solution, which is precipitated by alcohol. During this solution a portion of the farina is converted into malic and oxalic acids. It is dissolved likewise by muriatic acid.

Farina is insoluble in alcohol and ether.

Starch is dissolved by strong solution of caustic potash; the liquid is gelatinous and opal-coloured, and is decomposed by the acids.

It is precipitated from its aqueous solution by acetate of lead, per-muriate of tin, and barytic water, but suffers no change by the addition of silicated potash.

DCCXIV. Farina, or fécula, exists in considerable abundance in several species of plants, but is often so mixed or combined with other proximate principles as not to be readily separable. It may be obtained from the roots and stems, as well as the grains of vegetables, and the varieties are known in commerce by the names of Sago, Salop, Cassava, Indian arrow-root, Tapioca, &c. They are nutritive, and afford a valuable article of food to the sick, and the valetudinarian.

1. *Sago* is the product of the *Cycas circinalis*, a species of palm growing on the islands of the Indian ocean. The pith obtained from the tree is washed with cold water until the farina is separated from the other parts of the plant; the emulsion passes into a receiver, where the solid part subsides, the water is then drawn off, and the residuum when half dried is formed into grains by being pressed through a perforated funnel. It is said to acquire its gray colour while drying in an artificial heat.

2. *Salop* is prepared from the different species of *Orchis*, particularly the *orchis mascula*. It is obtained from its bulbous root; it is in the form of powder as imported; and as it possesses similar properties, it is applied to the same uses as sago.

3. *Cassava* is of American origin, and is procured from the roots of the *Jatropha mannihat* or *mannihot*, which by pressure yield a poisonous juice; yet the sediment from it, if well washed, is perfectly innocent. The cassava was used by the natives of those parts of South America in which it was prepared, as bread; and even now it is not unfrequently met with in some of the West-India islands. It appears in the form of broad sheets. Instances have occurred, in which persons have been poisoned by eating of cassava bread which was not carefully prepared.

4. *Arrow-root* possesses the same general properties as the above, and is obtained, for the same purposes, from the *Maranta arundinacea*. Of the origin of *Tapioca* I am ignorant.

The farinaceous grains yield a large proportion of farina. According to the analyses of Vogel wheat flour produces from 68 to 74 per cent. of starch; and rice, according to Braconnot, contains 85 parts in 100 of the same principle;* a fact which has been confirmed by Vauquelin.†

It is well known that starch of a good quality may be obtained from the potatoe, by rasping the root, putting the soft pulp upon a sieve, and pouring upon it successive portions of cold water; the latter acquires a milky appearance, and on standing deposits a sediment, which exhibits all the properties of starch. Indeed, says Dr. Thomson, it goes much further, a smaller quantity being sufficient to form a thick paste with water than is required of wheat starch. It has a very perceptible crystallized appearance, and is much heavier apparently than common starch.‡

* Annals of Philosophy, vol. xii. p. 38. † Ibid, vol. xiii. p. 151.

‡ System of Chemistry, vol. iv. p. 84, 5th ed.

From what has been remarked it will be evident that Farina or Starch is one of the most nourishing of the substances derived from the vegetable kingdom. The potatoe and rice, for example, are composed of farina with a small proportion of other principles; yet their powers of supporting life have been amply demonstrated by experience. It is even contained in many of the noxious vegetables, and may be separated from, without retaining any of the poisonous qualities of the roots of the *Arum maculatum*, the *Hyosciamus niger*, and the *Atropa Belladonna*.

SECTION III.

Of Sugar.

DCCXV. Sugar exists in different proportions and at different periods of growth, in a multitude of vegetables; but for the purposes of commerce it is obtained only from the *Arundo Saccharifera*, or Sugar cane of the East and West Indies. The juices of this plant at certain periods of its vegetation are rich in saccharine matter, and, in order to procure it, the cane cut into small pieces and tied up into bundles, is subjected to pressure between two iron rollers. The liquid as it flows is caught in a leaden receiver, from which it is immediately transferred to another large vessel, called the clarifier. Here it is mixed with lime in the proportion of about 1 pint to 100 gallons of the juice, and exposed to a temperature of 140° . The use of the lime is to combine with the acids which may be present, and to precipitate them in combination. After the fire is extinguished and as the liquid cools, a thick scum forms upon the surface, and the juice is drawn off either by a syphon, or through an aperture at the bottom of the vessel. It is then boiled for some time, and the impurities which rise to the surface are removed by skimming. When the bulk of the liquid is sufficiently diminished, it is introduced into another boiler, and if necessary

another portion of lime is added ; from this it passes to a third, and even a fourth boiler, until a sufficiently concentrated solution is obtained, when it is run into the *cooler*, a vessel which is formed of wood, and of which the depth, compared with the superficies, is small. As its temperature falls, the sugar concretes, or *grains*, as it is technically called, and is thus separated from the uncrystallizable part, which is familiarly known by its commercial name of *molasses*. The solid portion is then collected and enclosed in hogsheads, the ends of which are perforated and slightly closed with plantain leaf, to allow the liquid part to flow off. It is then *muscovado* or raw sugar. In this state it is in the form of dark coloured crystalline grains, moist, and somewhat viscid, and impure.

In order more effectually to remove the molasses, and to obtain the sugar in a purer state, it is subjected to the process of *claying*. The viscid juice from the last boiler is run into conical moulds, their apices being placed downward, for the purpose of draining the molasses, after which, caps of clay moistened with water are applied to their bases, and this water in slowly passing through the moulds dissolves and removes the molasses and colouring matters. By this process the sugar is said to lose $\frac{1}{3}$ in weight, but it becomes white, is obtained comparatively pure, and is sold by the name of *clayed sugar*.

For the purposes of luxury the sugar is made to undergo a series of operations similar in principle to the above, the solution is clarified by bullocks' blood, and when concreted, it is called *refined sugar*.

A gallon of juice as it comes from the cane yields about one pound of sugar.

Sugar has also been obtained in considerable quantities from the *Acer Saccharinum*, or the Sugar maple of North America, and from the root of the common Beet.

According to Dr. Rush the method practised in the interior of the United States to procure sugar from the juice of the maple, is as follows.—The tree when from 2 the 3 feet in

diameter is bored with an auger in the months of February, March, and April, to the depth of 2 inches. The perforation is made in an inclined direction, and wooden spouts are introduced to receive the sap as it flows from the wound. The process terminates in about 6 weeks, and the average quantity of juice obtained from each tree is about 25 gallons, which yield 5 pounds of sugar. The juice thus procured is boiled down, clarified, and crystallized in the same manner as is practised in the West Indies.

The process for making sugar from the juice of the beet originated in Germany; the art was practised to some extent in France while her external commerce was interrupted, and the manufacture, it is said, is still continued by M. Chaptal. Experiments were made in relation to this point by Achard, Lampadius, and Hermsteadt. From 125 pounds of beet, the latter obtained $5\frac{3}{4}$ of sugar, and $1\frac{7}{8}$ of molasses. Whence it appears that the juice of this root is richer in saccharine matter, than that of the maple; for according to Rush it requires 40 pints of maple juice to produce 1 pound of sugar.

DCCXVI. Sugar, however obtained, when perfectly pure is of a fine white colour, of a granular semi-crystalline appearance, brittle, and of a strong and purely sweet taste. It is phosphorescent, and this property may be developed by rubbing together two pieces in the dark. Some varieties have a peculiar flavour, arising no doubt from intermixture with other vegetable matter. It is extremely soluble in water, an equal weight being dissolved at 50° ; and any quantity at the temperature of 212° . A strong solution of sugar, which is thick, ropy, and adhesive, is called *syrup*.

Sugar is susceptible of crystallization, and crystals may be obtained by sufficiently evaporating its aqueous solution. They go by the name of sugar candy. The usual mode of procuring them is to dissolve sugar in white wine, the solution is boiled, the impurities which rise to the surface are removed, and the liquid is clarified by whites of eggs or isin-glass; when sufficiently concentrated, it is run into a vessel,

into which have been put small twigs or threads, and these foreign bodies, answering as nuclei, attract the particles as they are deposited, and at the end of the process exhibit beautiful 4 or 6-sided prisms, bevelled at each extremity, transparent and of some hardness.

Sugar is soluble in alcohol, but not in so large proportion as in water; neither is the solution so permanent, for on standing for some time, a portion is deposited in regular crystals.

Sugar with Acids and Metallic Oxides.

DCCXVII. The acids operate upon sugar either to decompose it or to alter the proportions of its elements.

With sulphuric acid the effect is almost immediate. The mass becomes black, and so much charcoal is evolved that it may be separated by the addition of water, and filtration. Water and acetic acid are said to be formed.

The phenomena with muriatic acid are somewhat similar; the sugar is decomposed and charcoal is evolved.

The action of nitric acid upon sugar is more important, and has been investigated with more precision. When added to each other and gently heated, effervescence takes place, nitric oxide gas is disengaged, and there remain in the vessel malic and oxalic acids. One hundred parts of sugar yield by this mode 58 parts of oxalic acid.

Several of the vegetable acids act upon sugar in such a way as to weaken, if not destroy, its power of crystallizing.

The alkalies and alkaline earths combine with sugar when dissolved in water, and weaken its taste, but its sweetness is restored by the addition of sulphuric acid in quantity sufficient to neutralize the base. It also unites with oxide of lead, but decomposes some of the peroxides of other metals. It has this effect on peroxide of manganese, when aided by an acid.

If sugar be mixed with chlorate of potash, and the mixture be heated, or touched by a drop of sulphuric acid, a lively combustion immediately ensues. The same effect is produced upon many others of the proximate principles of vegetables; and this method has been proposed and practised by M. M. Gay-Lussac and Thenard to ascertain the proportions of their ultimate elements.*

According to the experiments of Cruikshanks, the sulphurets, hydro-sulphurets, and phosphurets, at least those which decompose water, alter the constitution of sugar.†

DCCXVIII. On exposure to heat the colour of sugar changes to black, it swells up and produces a vapour of a peculiar smell which has been called *caromel*. In a higher heat it burns with flame. Subjected to distillation in close vessels it yields water, pyro-mucous acid, which is a compound of vinegar and empyreumatic oil, carbonic acid, and carburated hydrogen gases, and charcoal. Its ultimate elements, therefore, are carbon, oxygen, and hydrogen; and the following are the proportions as stated by different chemists;

Carbon	-	28.00‡	-	42.47§	-	41.48¶
Oxygen	-	64.00	-	50.63	-	51.47
Hydrogen	-	8.00	-	6.90	-	7.05
		<hr/>		<hr/>		<hr/>
		100.00		100.00		100.00

The analyses of the two last are most correct.

DCCXIX. Sugar may be prepared artificially, and the process of effecting it was first published by Kirchoff, a Russian chemist. It consists in boiling in a tinned copper vessel 200 parts of water and $\frac{1}{2}$ part, or according to Vogel, 1 part of sulphuric acid, and gradually adding to it 100 parts of starch previously mixed with 200 of water. The ebullition is to be continued for 36 hours, the water being occasionally renewed. Powdered charcoal in small quantity is then

* Recherches, t. ii. p. 265.

† Rollo on Diabetes.

‡ Lavoisier.

§ Gay-Lussac and Thenard.

¶ Berzelius.

to be added, and afterwards chalk, for the purpose of saturating and removing the acid. By filtration the sulphate of lime will be separated, and the clear liquid is to be evaporated to the consistence of a syrup; when set aside for a few days sugar will be deposited in the form of grains. Vogel has shown that if the proportion of acid be increased the process may be completed in a shorter time. Saussure considers this sugar to be formed by the union of water with the starch; it has been ascertained that the acid undergoes no change, and that no gas is extricated, though the starch increases in weight by its conversion into sugar. The sugar thus obtained resembles that which is procured from the juice of the grape.

This juice yields, according to Proust, from 30 to 40 per cent. of this substance. This kind of sugar is neither so sweet nor of such consistence as that of the sugar-cane. It was obtained by saturating the acids in the juice by an alkali, and concentrating the solution by heat; after the deposition of the salts it was managed in the usual way, and produced a brown sugar, which consisted of 75 parts of crystallizable sugar, and 24.44 of molasses, with minute portions of gum and malate of lime. According to the analysis of Saussure, the sugar of grapes consists of 36.71 of carbon, 56.51 of oxygen, and 6.78 of hydrogen. If this be correct, this species contains less carbon and more oxygen than common sugar.

Sugar is formed during the germination of the farinaceous grains, in the process of malting, and may be obtained in solution in water. The liquid is called *wort*, and when evaporated to a certain degree it produces a species of molasses. It is in this way prepared from wheat in the interior of the United States, and from two bushels of the grain, seven gallons and three quarts of molasses, it is said, may be obtained.

The uses of sugar are too familiar to require description.

Sugar, or an analogous principle, is found in considerable proportion in two other substances, viz. Manna and Honey.

DCCXX. *Manna.* This substance is the inspissated juice of a species of ash, the *Fraxinus Ornus* of botanists, a tree growing in Sicily and Calabria. It is the result either of spontaneous exudation, or of incisions made in the stem and branches, the liquid as it flows out being hardened on sticks or small spouts placed for the purpose. The flake manna, which is purest, is in the form of flattened masses, white with a shade of yellow, of a sweet, but rather unpleasant taste, and consisting apparently of a congeries of capillary crystals. It is soluble both in water and alcohol. When the spirituous solution, made with the assistance of heat, is allowed to rest for a few days, a large portion of the manna is deposited in crystals, radiating from the centre, white, and of an agreeable sweet taste. When these are separated and the solution is evaporated, a light brown mass is obtained, which probably consists of the substances that impart the peculiar taste and purgative quality to manna.

DCCXXI. *Honey* is a vegetable product always found in the flower, chiefly at the base of the pistil, whence it is collected by the bee, and deposited in the hive. It derives its flavour from the plants by which it is produced; and Dr. Barton has shown that it is occasionally poisonous.

Honey contains a large proportion of saccharine matter; which is of difficult crystallization; when solid it is in spherical masses, resembling the sugar of grapes. Proust distinguishes two kinds, the one fluid, yellow, and viscid, the other solid and in grains. They are both soluble in water, and in alcohol. The taste of honey results from the presence of some other proximate principle, perhaps volatile oil.

SECTION IV.

Of Jelly.

DCCXXII. The claims of this substance to be considered as a distinct vegetable principle are not very strong. It may be obtained by the expression of different species of

berries ; it also exists in the acid fruits, in tamarinds, and the pulp of the cassia fistula. The juice of berries on standing concretes into a soft gelatinous substance, from which the colouring matter may be in part removed by the affusion of cold water.

It is a tremulous substance, soluble only in a slight degree in cold water, but easily dissolved by boiling water, and again gelatinizes on cooling. If the solution be long boiled, it loses this disposition to become solid, and assumes the character of mucilage. Whence it happens, that, in the formation of jelly from fruits, if the quantity of sugar added is not sufficient to absorb the aqueous parts of the juice, and it is necessary to boil it for some time to give it a proper consistence, it frequently happens that it loses the property of gelatinizing on being cooled. When jelly is evaporated it becomes dry and exhibits properties analogous to those of gum. It combines with alkalies, but is decomposed by acids. By distillation it affords much pyro-mucous acid, a little empyreumatic oil, and a trace of ammonia.

The above description is taken from the experiments of Vauquelin, published in the *Annales de Chimie*.

SECTION V.

of Oil.

DCCXXIII. This important vegetable product has been divided into two species. Some oils are volatile, and on exposure to heat, are entirely evaporated, while others cannot be vaporized without undergoing a partial decomposition ; the former are odorous, acrid to the taste, and soluble in spirit of wine ; while the latter are nearly insipid, destitute of colour, and insoluble in alcohol. Hence the one species has been described by the name of volatile, or essential, the other by that of fixed, or expressed oil.

Fixed Oil.

DCCXXIV. The property of forming oil is almost exclusively confined to those plants which are bicotyledonous, and the cotyledons when bruised in water produce an emulsion or milk-like fluid. Many of the oils are liquid, but some appear in the form of soft solids, and have been called *vegetable butters*, such, for example, as those of the *cocoa* and *nutmeg*.

The liquid oils are obtained either by expression, or by macerating or boiling the seed in water, the oil separates, and in consequence of its inferior specific gravity floats on the surface.

The purest of the vegetable oils are colourless, or have a slight tinge of yellow, transparent, insipid, and inodorous, or nearly so, lighter than water, and incapable of uniting with that liquid. They have an unctuous feel, and produce a greasy stain. At a temperature approaching the freezing point of water, they become solid, and it has been demonstrated by Braconnot that when thus frozen, placed between folds of blotting paper, and pressed, a liquid flows out, and may be separated from the paper, by immersion in hot water. Hence it appears that oil may be proved to consist of two distinct substances, the one solid, the other liquid.* Chevreul had before this demonstrated the same fact with respect to the animal fats, and had given to the solid the name of *margarine*, and to the liquid that of *fluid fat*.† He has since described them by the titles of *Elaine* and *Stearine*.

DCCXXV. Fixed oil cannot be vaporised without undergoing partial decomposition. When heated to about 600°, a vapour rises from the surface, carburetted hydrogen gas is evolved, and the oil, which is thus distilled, loses its bland taste, becomes acrid, lighter than before, and has its colour changed to a yellow or deep brown. If the distillation be rapid and at a high heat, the products are empyreumatic oil, an acid liquid, carbonic acid and carburetted hydrogen gases, and charcoal.

* Annales de Chimie, t. xciii. p. 225.

† Ibid, t. xciv. p. 73.

In consequence of the high temperature necessary to the vapourisation of oil, the presence of water is dangerous ; hence in the boiling of lint-seed oil, the process is conducted in the open air, in dry weather, and at a distance from combustible substances. A single drop of water falling into the vessel would, by its conversion into vapour and its subsequent decomposition, suddenly produce a large bulk of inflammable air, which must have the effect to dash the boiling oil from the vessel in every direction.

The boiling of some of the oils produces in them peculiar changes, by which they are rendered fit for the purposes of the painter, the printer, and the varnisher. They are known in the arts by the name of *drying oils*. After this process they become more deeply coloured, and of greater consistency, and acquire the property of becoming solid, or of forming a solid, when applied in a thin film upon a surface, and exposed to the air. Such are nut and lint-seed oils. Printers' ink is composed of one of these oils, mixed up with lamp-black in the proportion of about 16 ounces of the former to $2\frac{1}{2}$ ounces of the latter.

This property of drying is not characteristic of all the oils. There are some, for example those of the almond and the olive, which on exposure to the air become thick, opaque, and of a whitish appearance, and hence have been called *Fat oils*. These oils when long in contact with the air change their colour to a light green, and acquire an acrid, disagreeable taste and odour. They are then said to be *rancid*. This change is the result of the absorption of oxygen, which combines with the whole or a part of the oil and forms with it a peculiar acid, called the *Sebacic*.

DCCXXVI. In peculiar circumstances there appears to be a reaction between the elements of the drying oils, and combustible substances by which, when atmospheric air is admitted, spontaneous combustion takes place. This fact was first noticed in Russia. It was observed that frequent fires were produced in the naval and military warehouses at

St. Petersburg, under circumstances which could not be supposed the result of accident ; and it was some time before it was discovered, that the combustion was spontaneous. As soon as this fact was ascertained, it was proved by experiment that when hemp, or flax, or linen cloth was moistened with drying lint-seed oil, laid in a heap, and closely pressed, it soon grew warm, began to smoke, and in the course of from 12 to 30 hours, took fire, and was consumed. The time required to produce this effect varied with the nature of the material, the degree of pressure applied, and the quantity of oil employed. In some trials the mass burst into flame in 9 hours, and in others in 16 or 20 hours from the commencement of the experiment. It is remarkable that the experiment succeeds only with the drying oils.*

Animal, oily, or fatty substances appear to be exposed to similar changes. An intelligent tallow chandler informed me that “in trying the rough tallow, when it was reduced to scrap and transferred into a barrel, he had frequently known an apparent increase of heat to take place in the scrap, so that within 10 or 12 hours some of it in the middle of the barrel would be reduced almost to charcoal, and the tried tallow, which was quite clear and transparent at first, would have the dark colour of chocolate.”

DCCXXVII. Chlorine and iodine deprive the oils, even at common temperatures, of a portion of their hydrogen, by which the one is converted into muriatic acid, and the other into hydriodic acid.

Phosphorus and sulphur are dissolved by the fixed oils. Phosphuretted oil may be formed by triturating them in a mortar, or more expeditiously by heating 15 or 20 grains of phosphorus in 2 or 3 ounces of olive oil in a phial with frequent agitation. This oil may be rubbed upon the body which is rendered luminous, without being injured by the application.

Sulphuretted oil is produced when flowers of sulphur are boiled in oil. The liquid has a reddish colour, is thick and

* Repertory of Arts, vol. iii. p. 95.

glutinous, gives out the odour of sulphuretted hydrogen, and after a while deposits a portion of sulphur in well defined crystals.

The acids either unite with the oils or decompose them. Their mutual action increases with their temperature, and it is greater with the drying than with the fat oils. With strong nitric acid a mutual decomposition is rapidly produced, and a substance of the nature of wax, or thin resin is, according to Trommsdorf, formed; the oil is sometimes inflamed.

The mutual action of the fat oils and the alkalies is better known, as it gives rise to more important results. If a portion of olive oil be intimately mixed with an equal bulk of a strong solution of caustic soda and be allowed to remain at rest, a solid compound will be formed, which will exhibit all the properties of soap. This substance then is the result of the combination of oil and alkali.

Soap.

DCCXXVIII. The consistence of soap depends upon the alkali employed; with potash oleaginous substances produce a soft, and with soda a hard saponaceous compound. In both instances it is necessary to employ the alkalies in their caustic state; hence in the manufacture of every species of soap the first steps of the process are the same, viz. to deprive the potash or soda of its acid.

In the formation of soft soap the ashes of vegetables mixed with quicklime are lixiviated with water, which dissolves the carbonate of potash, and from this the carbonic acid is abstracted by the lime. This solution is then mixed in certain proportions with the ordinary oils, or more frequently with the different kinds of animal fat, and boiled, fresh portions of *ley* being occasionally added. A combination takes place, and a thick liquid is formed, which when cooled becomes converted into a soft jelly-like mass.

Hard soap is formed from soda, which is obtained by the lixiviation of the barilla of commerce. Carbonate of soda is dissolved, and by the use of quick-lime in the proportion of about 1 pound to 6 pounds of barilla, it is rendered caustic. The solution is drawn off, and a fresh portion of water added, which in its turn is removed, and replaced by another portion, so that three separate leys are formed, of which the first is by far the strongest. These leys are successively boiled, the weakest first, with a determinate quantity of oil, until a compound is formed which separates from the aqueous parts and rises to the surface. This compound, after the liquid is withdrawn, is melted in contact with a weak ley; it is allowed to cool, the liquid is drained off, the mass is melted a second time, and in that state run into moulds containing a small quantity of powder of lime, where in the course of a few days it concretes into hard soap. In some places the soda is obtained from common salt. The process is at first conducted with potash, but toward the conclusion the soap is rendered susceptible of concretion by the addition of a determinate quantity of muriate of soda, which is decomposed by the potash, the soda is disengaged and combines with the oil, while the potash unites with the muriatic acid, or to speak more correctly, the chloride of sodium is decomposed, the oxygen of the potash passes to the sodium by which soda is formed, while the potassium combines with the chlorine and constitutes a chloride which remains dissolved in the liquid.

Such is a very general outline of the process for manufacturing soap.

Several species of this compound are employed in commerce. The common bar soap, which is of a yellow colour and resinous appearance, is formed by the addition of rosin to the ingredients of the ordinary hard soap. The marbled, veined soap, or wash-ball, is coloured brownish-red by green copperas, the sulphate of iron of the chemists, by adding its solution to the soap during its last boiling, and incorporating them by agitation. The alkali present decomposes the sul-

phate, and the black oxide thus separated soon becomes converted to the red or peroxide. This is the colouring matter of Castile soap. Soap is coloured blue by azure, or finely powdered smalt ; and red by red-lead, or vermillion. The transparent soaps are formed from the solution of white soap in alcohol or spirits of wine.

From the experiments of D'Arcet sen'r, and of Lelièvre and Pelletier, it appears that the oils or animal fats are not all equally susceptible of forming soaps. Those which succeed the best are, 1. Oils of olive, and of sweet almonds. 2. The animal oils, such as tallow, grease, and butter ; and lastly, some of the vegetable oils.

All the hard soaps contain a large proportion of water, which is gradually dissipated on exposure to the air ; the mass shrinks, and even cracks in different parts. Chaptal found that a piece of soap lost by drying no less than 56 parts in 100. White soap consists, according to Thenard, of about 4.6 parts of soda, 50.2 of fatty matter, and 45.2 of water. According to Dr. Thomson, the proportions, supposing the mass to be pure, are 64.49 of fatty or oily matter, 7.57 of soda, and 27.94 of water ; but he has met with soap which contained $\frac{50}{100}$ of water.

The theory of saponification, if the term may be allowed, has been developed by the researches of Chevreul. According to his experiments, vegetable oils and animal fats are constituted of two substances, the one fluid, the other solid ; to the former he gave the name of *eläin*, and to the latter that of *steärin*. When these substances are acted upon by the alkalies in the process for manufacturing soap, a reaction, it would seem, must take place between the elements of these substances, and probably the oxygen of the air, by which two acids are formed, the margaric and olëic, and these combining with the alkaline bases constitute saponaceous compounds. We shall advert more particularly to the properties of these acids hereafter.

DCCXXIX. All the soaps which are compounds of oils or animal fat with alkalies, are soluble in water, and their detergent properties are dependent upon the presence of the alkali. The power of water to effect this solution is a good criterion of its purity. When it contains no uncombined acid, nor any neutral salt, the soap readily dissolves and forms with it an uniform, smooth, and nearly transparent liquid ; such are rain and spring waters. But if neutral salts, and particularly those with earthy bases, be present, there will be a mutual decomposition of the soap and the saline compounds, the earthy bases will be precipitated, and the oleaginous substances be separated in flocculi. This is the case with well-water, or that which is found in the vicinity of the sea. Such waters are said to be *hard*. This hardness may be removed to a certain degree by the addition of pearl-ash.

Soap is likewise soluble in alcohol, but in smaller proportion than in water ; and when a saturated solution is made at a high temperature, the liquid, on cooling and being allowed to remain for some time at rest, changes to a solid of some firmness and transparency.

The solutions of soap are decomposed by the acids, and the oil or fat is probably disengaged in the form of the acids above mentioned. The substance separated is soluble in alcohol.

Oil is also susceptible of combining with ammonia and the oxides of the metals of the second division.

Ammoniated oil may be formed by adding equal volumes of olive oil and liquid ammonia to each other and mixing them by agitation. It has a white opaque appearance, gives out the odour of ammonia, and was used in medicine by the name of *volatile linament*. It is doubtful whether it can be regarded as a true soap.

The soaps formed from oils or fat, and lime, magnesia, &c. are of little consequence.

With the oxides of lead, if the process be conducted with heat, the oils combine in such proportion as to become solid on cooling. Lytharge, or common plaster, is prepared by boiling together 1 part of semi-vitrified oxide of lead, and 2 parts of olive oil. The concretion of the mass is probably owing to the combination of the oil with a portion of the oxygen of the oxide.

Oil is capable of combining with some of the proximate principles of plants. The union is effected by trituration, as for example, with gum or sugar; if water be added, an opake milk-like fluid is formed, which has received the name of emulsion. In this case the particles of the oil seem to be merely suspended in the liquid. Some of the kernels, such as those of the almond, which contain both oil and fecula, produce, when bruised and washed with water, an emulsion. Solution of gum appears to suspend oily particles longer than that of sugar or fecula.

Several varieties of oil are employed in commerce. Their general properties are the same, though they differ from each other to a certain degree in colour, consistency, transparency, taste, odour, and the power of becoming solid on long exposure to the air.

Uses of Fixed Oils.

DCCXXX. The uses of these substances are many and important. They enter into the composition of some of the varnishes, and of printing ink. They are the media by which pigments are applied to other bodies; they are employed in medicine, and the oil of olives constitutes an article of food. Oils are inflammable, and from this circumstance and the ease with which they are procured, are very commonly used in the production of artificial light. To produce this effect it is requisite that the oil should be raised in vapour, and inflamed in that state. Hence arises the necessity of a wick, composed of filaments of cotton, into which the liquid rises by ca-

pillary attraction. When heat is applied to the upper extremity the oil is vaporized, it comes into contact with the air, its elements unite with atmospheric oxygen, and flame is produced. In proportion as the oil is consumed at the wick, it is renewed from below, and the combustion goes on until its food is exhausted. It is obvious that to cause the total consumption of the oil there must be a certain proportion between the vapour raised and the oxygen applied. If the former be in excess, one portion only will be inflamed, while the other will pass off in the form of a thick and disagreeable smoke. This circumstance will take place whenever the wick is so large or thick as to prevent the access of the air to the whole of the vapour. It may frequently be observed in a lamp of the common construction. To remedy this inconvenience, the wick in some lamps is made broad and thin, so as to expose a large surface to the air. By far, however, the greatest improvement is that which was made by Argand in the construction of the lamp which goes by his name. The principle upon which it is formed, is to cause a current of air to pass over both surfaces of a thin circular wick of cotton, so that by the rapid motion through a tube of glass or of metal of large and fresh portions of air, all the oil which has been raised in vapour shall be supplied with a sufficient quantity of oxygen to be completely converted into carbonic acid and aqueous vapour, and no smoke nor offensive odour shall be produced. This lamp, as it is well known, gives a steady and uniform light, the intensity of which has been estimated by Count Rumford to be equal to that of 10 wax candles, each $\frac{3}{4}$ of an inch in diameter ; an estimate, however, which is much too high. For chemical purposes, Mr. Webster has added a second wick to this kind of lamp, and the temperature excited in it is sufficiently high to complete a multitude of processes in which heat is required. According to Hassenfratz, the quantity of light in lamps of Argand's construction is not so great as might be expected, because the light from the interior of the wick is diminished in intensity in

passing through the column of flame. Dr. Murray infers that a lamp with a flat ribband wick, on the common construction, with a glass chimney placed over, so as to admit of a current of air, and of rendering the flame steady and uniform, gives nearly as much light as an Argand's lamp.* The *Liverpool lamp* appears to be constructed upon this principle, but in consequence of the chimney being raised a short distance to admit the air, a current is directed upon the flame, which causes it to give a flickering and unsteady light. Mr. Leslie observes that with regard to the relative advantages of different lamps, the difference in point of economy is not very material. The light shed by the several inflammable substances with which we are acquainted, may vary in its purity and degree of concentration, but its absolute quantity appears always nearly proportional to their rate of consumption.* Count Rumford, however, found that the quantity of light appeared to be greater when several flames were brought very near to each other, than when separated. Argand's lamp has a decided advantage over the common lamp in producing no vapour nor odour. In the latter the temperature is not sufficient to cause the combustion of the whole of the oil, and the lamp is very liable to smoke.

Volatile, or Essential Oil.

DCCXXXI. The odour of plants apparently depends upon the presence of volatile or essential oil, or what the earlier chemists called *spiritus rector*. These oils are found in various parts of the vegetables which form them, sometimes in the fruit and flowers, sometimes in the bark, and at others in the wood. Some of these oils are obtained by simple pressure, others by distillation with water, for though none of them is vaporised below 309° of Fah., yet they pass over with the vapour of water. The plant, together with a quantity of water, is

* System of Chemistry, vol. iv. p. 161, 4th ed.

+ Inquiry, p. 449.

put into an alembic and exposed to heat; aqueous vapour and the vapour of the essential oil pass into the receiver and are condensed; the two liquids, which are of different specific gravities and do not combine, separate, and the oil may be obtained by putting them into the separatory vessel, which is nothing more than a glass funnel with a stop-cock at the bottom; the liquid which is lowest may be thus cautiously withdrawn.

DCCXXXII. Volatile oil, however procured, is in general liquid, highly combustible, of a sharp acrid taste, and of an odour similar to that of the plant from which it is extracted. The specific gravity of most of these oils is less than that of water. Their colours are various; those of turpentine, roses, bergamotte, and rosemary, are colourless and transparent; oil of wormwood is deep green, of lemons yellow, of cinnamon and cloves reddish yellow, of mint light green, of anise-seeds greenish, and of chamomile blue. They differ as much likewise in consistency. The oils of turpentine, bergamotte, roses, and some others, are very fluid or limpid; those of cloves, cinnamon, anise, mace, &c. are oily and viscid; while some have the consistence of butter, as those of nutmeg, hops, and pepper.

On exposure for some time to the air, the volatile oils gradually lose their odour, increase in colour and consistency, and some of them even become solid, while others deposit crystals of a peculiar acid, called the *benzoic*; or a substance which has the characters of camphor.

When acted upon by heat in close vessels, they distil over unaltered at a temperature higher than that necessary for the active vaporisation of water. According to Gay-Lussac none of them boils at a temperature lower than 309° of Fah. If heated sufficiently in contact with the air they readily take fire, burn with vehemence, and produce abundance of dark coloured smoke, which subsequently condenses into a light charcoal. Lamp-black is formed in large quantities in the Southern States by the combustion of the pitch pine, which contains an essential oil.

These oils are inferred to be composed of hydrogen, carbon, and a small proportion of oxygen, and differing from the fixed oils in containing a larger proportion of hydrogen.

As these oils are inflammable by raising, so they may be rendered solid, by diminishing their temperature. They freeze at very different degrees of the thermometer. The oil of anise becomes solid at 50° ; those of bergamotte and camella at about 23° , and oil of turpentine at 14° .*

DCCXXXIII. These oils being volatilized on exposure to heat, this property may be used as a test of their purity. The essential oils in consequence of the small quantities in which they are procured, and the labour and expense of the process, are sold at a high price; hence it has been found more profitable than honest to increase their bulk by the addition of some less valuable article. The adulterating substance is either oil of turpentine, oil of almonds or of olives, or alcohol. The first may be discovered by the odour which exhales when a drop of the suspected oil is put upon a piece of paper and exposed to heat; the second may be detected by the greasy stain which a drop of oil leaves upon paper, after having been exposed to heat; and where alcohol is present it is shown by the milk-like fluid it produces with water.

Light has the effect to increase the colour and consistency of the essential oils. Oil of turpentine is acted upon by chlorine and part of it is converted into a white and dense oily substance, which has the odour of the nutmeg.†

The volatile oils dissolve sulphur by the aid of heat, and produce reddish coloured solutions of a disagreeable taste and foetid odour, from which the sulphur is precipitated in a crystallized state by rest. These compounds have been called *Balsams of sulphur*. Phosphorus is likewise soluble, though sparingly, in oils.

* Thomson's System, vol. ii. p. 355, 5th ed.—The freezing point of oil of turpentine here noticed must be a mistake; for I once exposed some which had been twice distilled, to a natural cold of -12° , without impairing its fluidity.

† Dr. John Davy.

The mutual action of potash and oil of turpentine has given rise to a preparation which has been called Starkey's soap. It is formed by long trituration of the materials. Dr. Thomson infers that the oil first becomes a resin by the absorption of oxygen, and that the oil will not combine with potash.

DCCXXXIV. The acids decompose and are decomposed by the essential oils with much greater violence than by the fixed. Sulphuric acid added to oil of turpentine causes an immediate rise of temperature, the mixture grows black, charcoal is disengaged, and sulphurous acid and carbonic acid gases are evolved. A species of resin appears likewise to be formed. With nitric acid the action is still more rapid, abundance of red fumes are evolved, and the oil is sometimes inflamed. This effect however will not be produced unless the acid be in a concentrated state, which is not the case with that which is met with in the shops; the experiment always succeeds when the acid is employed in its fuming state, as it exists immediately after its production by the distillation of nitrate of potash and sulphuric acid. Nor is it necessary in this case to add, as is usual, a small proportion of sulphuric acid. If the acid be added to oil of turpentine in small portions at a time, a mutual decomposition takes place, some of the vegetable acids, a substance analogous to resin, and probably tannin are formed, and an odour somewhat fragrant is diffused through the apartment.

Muriatic acid forms with oil of turpentine a substance similar to camphor.

The essential oils are insoluble in water; yet when distilled together the former acquires in a slight degree the taste and odour of the latter.

The proper solvent of these oils is alcohol, but it does not dissolve the same quantity of each; for some are soluble in nearly all proportions, some in large but limited proportions, and others only in small quantities. These solutions are decomposed by the affusion of water, the mixed liquids becoming white and turbid, and the oil finally separating altogether from the water.

They may be suspended for some time in water by the medium of gum, fecula, or sugar.

The oils, or at least some of them, are readily soluble in ammoniated alcohol. They also dissolve the fixed oils.

DCCXXXV. If we except the oil of turpentine, few of the essential oils are applied to any other purposes than those of luxury and medicine. The most valuable, or those which are both fragrant and costly, are expended as perfumery, others are employed as condiments, or used in medicine as diffusible stimulants.

SECTION VI.

Of Wax.

DCCXXXVI. Wax has been inferred to be fixed oil saturated with oxygen. It is a product of plants, exists in the fecula of the houseleek and cabbage, in the seeds or berries of the myrtle wax-tree, and constitutes the fine silvery down which covers the leaves and fruits of certain vegetables. Wax is likewise of animal origin, and is formed by the bee. Huber appears to have proved that it is secreted by the animal, and is not collected, as has been the general opinion, from plants. He infers that it comes from the honey, that this substance is a necessary part of the food of the bee, and that the pollen which is carried by it into the hive constitutes the food of the young after having gone through a certain preparation in its own system.* Yet the properties of bees-wax and of vegetable wax are so similar, that they may both be described under one head.

DCCXXXVII. Bees-wax is a solid substance of a yellowish colour, opaque, destitute or nearly so of taste and odour. It is brittle and breaks with a fibrous, conchoidal fracture. Its specific gravity is nearly that of water. In its purest state wax is beautifully white and translucent, and this char-

* Nicholson's Journal, vol. ix. p. 192.

acter may be imparted to common wax by melting it, drawing it into thin plates, and then exposing it to the alternate action of light, moisture, and atmospheric air, or in a shorter time by the action of chlorine.

DCCXXXVIII. When exposed to heat it melts at the temperature of 155° , if unbleached, at that of 142° , and its fluidity increases with the heat, until near to ignition, it then takes fire and burns with a clear white light. The products of its combustion are carbonic acid and water. Hence it is evident that it contains carbon and hydrogen; and oxygen has been found in it by M. M. Gay-Lussac and Thenard.* According to their analysis it consists of

Carbon	-	-	-	-	-	81.784
Oxygen	-	-	-	-	-	5.544
Hydrogen	-	-	-	-	-	12.672
						<hr/>
						100.000

or of

Carbon	-	-	-	-	-	81.784
Oxygen and hydrogen in the proportions necessary to form water						} 6.300
Hydrogen, in excess	-	-	-	-	-	
						<hr/>
						100.000

DCCXXXIX. The action of wax on the simple combustibles has not been investigated. It operates but feebly upon the acids, and produces no interesting compounds. The fixed alkalies are capable of combining with wax, and the union is effected by boiling them together, the solution on cooling is decomposed, and a portion of the compound rises to the surface in the form of flocculi. The ancients were accustomed to the use of a composition of this kind, and ac-

* *Rechères Physico-Chimiques*, t. ii. 317.

ording to Lorgna the Punic or Carthaginian wax which was employed as a ground for colours in encaustic painting, was composed of 1 part of soda united with 20 parts of wax.

Wax by the aid of heat readily dissolves in the fixed oils, and the compound is employed in surgery by the name of simple ointment.

DCCXL. At common temperatures wax is insoluble both in water and alcohol, but when the latter is heated to its boiling point, it takes up a small proportion, part of which is deposited as the solution cools, and the other is separated by the addition of water. To the portion dissolved Dr. John gave the name of *Cerin*, and that which was insoluble he called *Myricin*. Their properties are very similar.

It has been observed that the fixed oils on long exposure to the air acquire a solid consistence, and properties similar to those of wax, in consequence, as it has been supposed, of the absorption of oxygen. This change may be effected in a shorter time by pouring a little olive oil on the surface of diluted nitric acid and exposing the fluids to the action of light and the air.

DCCXLI. There exist some varieties of wax, of which that of the bay-berry, or myrtle wax-tree, the *myrica cerifera* of botanists, is procured in the largest quantity, and is the best known. It is obtained by the decoction of the seeds or berries in water. It differs from bees-wax chiefly in its colour, which is a full green.

SECTION VII.

Of Resin.

DCCXLII. Resins exist in considerable quantities in several vegetables, and constitute one of their most important proximate principles. They appear to bear the same relation to the volatile than wax does to the fixed oils. They are produced spontaneously from trees or shrubs either by a natural

opening or a wound, and in their recent state contain essential oil, which, when evaporated, leaves them in a solid state.

DCCXLIII. The resins are solid, brittle, of a conchoidal fracture, of various degrees of transparency, of a peculiar pellucid yellow colour, and of a faint but characteristic taste. They are non-conductors of electricity, and when excited are always negative, or opposed in their electric state to that of excited glass. Hence arose the terms resinous and vitreous electricity. The specific gravity of all the resins is greater than unity. They are inflammable, and after being melted, if the temperature be sufficiently increased, they take fire and burn with a dense reddish flame, producing abundance of smoke. The results of their combustion are carbonic acid and water. The analyses of *rosin* and *copal* by M. M. Gay-Lussac and Thenard may perhaps be taken as a correct view of the composition of the whole class.

1. *Rosin*.

Carbon	-	-	-	-	-	75.944
Oxygen	-	-	-	-	-	13.337
Hydrogen	-	-	-	-	-	10.719
						<hr/>
						100.000

or of

Carbon	-	-	-	-	-	75.944
Oxygen and hydrogen in the propor- tions to form water	-	-	-	-	-	} 15.156
Hydrogen in excess	-	-	-	-	-	
						<hr/>
						100.000

2. Copal.

Carbon	-	-	-	-	-	76.811
Oxygen	-	-	-	-	-	10.606
Hydrogen	-	-	-	-	-	12.583
						<hr/>
						100.000

or of

Carbon	-	-	-	-	-	76.811
Oxygen and hydrogen in the propor-	}					12.052
tion to form water						
Hydrogen, in excess	-	-	-	-	-	11.137
						<hr/>
						100.000*

DCCXLIV. The resins are insoluble in water, but if agitated with that liquid in their melted state, a combination appears to take place, and rosin thus managed becomes opaque, whitish and more ductile.

Resins and the acids react upon each other and produce changes varying with the nature of the acid employed. These changes have been particularly investigated by Mr. Hatchett.† With sulphuric acid the first effect is solution, then there forms a substance similar in properties to *tannin*, and this tannin is finally converted into charcoal. Nitric acid changes the colour of resins to a light yellow, and their texture to that of a spongy mass; if the contact be continued sufficiently long, there may be obtained by evaporation a viscid substance of a deep yellow colour, of a nature intermediate between tannin and vegetable extract.

Resins he found to be soluble in acetic acid. These solutions are decomposed by the alkalies. The same chemist ascertained that the resins were soluble in solutions of the alka-

* *Rechères Physico-Chimiques*, t. ii. pp. 313, 315.

† *Philosophical Transactions* for 1805 and 1806.

lies, and precipitated from them in the form of a curdy substance by the acids.

Resins are soluble in fixed and volatile oils, and in alcohol. Some of them dissolve with greater facility and in larger quantity in these liquids than others, but those which are least disposed to this kind of union have their solubility increased by the addition of camphor.

DCCXLV. Resins are obtained from a variety of plants, and they are somewhat modified by their states of cohesion, their colour, odour, and the accidental presence of other vegetable substances. Rosin is the product of the different species of Fir; the juice of the *Pinus Sylvestris* is common turpentine, of the *Pinus larix* Veniceturpentine, and of the *Balsamea Canada* balsam. When this juice first concretes it is in small masses and is called frankincense. Distilled in close vessels it yields oil, or spirit of turpentine, and the solid which remains is common rosin. Tar is obtained in the Southern States for the purposes of commerce by submitting billets of the pitch-pine to imperfect combustion, and the juice as it flows out runs into a hole or reservoir in the ground. It is a dark coloured tenacious substance, consisting of resin, essential oil, charcoal, and some acetic acid, with an empyreumatic odour. When the volatile oil is driven off by boiling the tar, the residue becomes solid and constitutes *pitch*. *Mastic* is the resin of the *Pistacea Lentiscus*, a native of Crete and the Grecian Archipelago; *sandarach* of the *Juniperis communis*; *labdanum* of the *Cistus Creticus*, growing in Syria and the Levant; *Botany Bay gum* of the *Acoroides resinifera* of New-Holland; *copal* of the *Rhus copallinum*, a native of Spanish America; *lac* is deposited on trees by the chremes lacca, an insect of Southern Asia.

Uses of Resin.

DCCXLVI. The principal uses of the resins in the arts is in the composition of varnishes, and for this purpose the

most valuable are Lac and Copal. The solutions of these substances are called Oil or Spirit Varnishes, according as they are formed with the oils or with alcohol. Those into which lac enters as a constituent part are coloured, while the varnish from copal is transparent. Considerable difficulty has been experienced in making copal-varnish from the insolubility of that resin; but this difficulty has been in a great measure overcome by the perseverance of Mr. Sheldrake. He has found that camphor promotes the solution of copal, and the details of the process may be found in the 9th volume of Nicholson's Philosophical Journal.

Gum Resin.

DCCXLVII. A variety of pure resin exists in what has been called gum-resin, which has been supposed to be a combination of gum and resin. It is very doubtful, however, whether this opinion of their constitution be correct, for many of these substances contain but a small proportion of gum, while they abound in one or more of the other proximate principles of vegetables. Their composition in fact has not been accurately investigated. These bodies in relation to medicine form an important class; and it is not a little remarkable that while the pure resins which have just been described are almost inert, the gum resins include some of the most active articles of the materia medica, such as gamboge, scammony, euphorbium, aloes, assa fœtida, &c. The properties of this class of bodies combine to a certain degree those of gum and of resin. They are partially soluble in alcohol and in water, the resin being dissolved by the former, and the gum or extractive by the latter. The aqueous solution is milky, and constitutes an emulsion, such, for example, as that of ammoniacum. They are also soluble in solutions of the alkalies, and acted upon by acids in a manner similar to the pure resins.

It may be remarked that the different species of gum, of resin, and of gum-resin, are all designated in commerce by the general name of *gums*.

SECTION VIII.

Of Camphor.

DCCXLVIII. Camphor, a substance which in many of its properties resembles the resins and essential oils, is the product of the *Laurus Camphora*, in which it is found ready formed between the fibres. It is imported in a crude state from Japan, and purified by sublimation in close vessels with quick-lime. Gay-Lussac proposes to distil it in a retort like a liquid, and condense its vapour in globular receivers of copper, which will be more expeditious and less expensive.*

Campher is in the form of large masses, translucent, beautifully white, of an unctuous feel, somewhat ductile, and not easily powdered. Its taste is pungent and bitterish, its odour peculiar and penetrating, and its texture crystalline and striated. It is volatile, and on exposure to the air diminishes in volume or evaporates.

When heated it melts, according to Gay-Lussac, at 349° , and is volatilized at 399° . It takes fire readily, burning with a bright flame and much dark coloured smoke, and if pure leaving no residuum. It consumes with more brilliancy in oxygen gas, and the products of the combustion are carbonic and camphoric acids and water.

DCCXLIX. The acids act in different ways upon camphor and give rise to varied results.

With sulphuric acid, it becomes yellow, is dissolved, partially decomposed, and disengages charcoal. Mixed with water it produces yellow oil, charcoal, and a substance similar to tannin.

Nitric acid dissolves this principle with facility, and the solution by rest separates into two portions, one of an oily

* Annals of Philosophy, vol. xiii. p. 67.

appearance, the other more fluid. The former, which has been called oil of camphor, is a compound of this substance with the acid, and it is decomposed by the addition of water. This oil is soluble in alcohol. Camphor is likewise soluble in the other acids, even those which are gaseous. It is dissolved by acetic acid, and by the addition of some of the essential oils a compound is formed analogous in properties to the celebrated *vinegar* of the three thieves who employed it as a preventive against the plague, while robbing the houses of Marseilles, which city was almost depopulated by the ravages of that disease.

DCCL. Camphor is slightly soluble in water and imparts to it its peculiar odour. It is remarkable that small fragments of this substance placed upon the surface of that liquid, immediately begin to move with velocity with a rotary motion until dissolved or evaporated; an effect which has been ascribed to the repulsive forces exerted upon the mass by its vapour as it passes off horizontally.

Camphor is readily dissolved by the essential oils and alcohol. Oil of turpentine takes up a large proportion, and if the solution be made with heat, a portion of it is deposited in the form of feathery crystals, as the liquid cools. The liquid contained in the tubes which are sold by the name of *weather glasses* is probably of this nature. They are said to indicate changes in the weather some hours before they take place, by the relative quantity or situation of these plumose crystals. They are in fact rude thermometers which indicate increase or diminution of temperature by the greater or less solvent power of the liquid. They afford a good example of philosophical quackery.

Alcohol dissolves $\frac{3}{4}$ of its weight of camphor; the solution is transparent, and is decomposable by water, the camphor being separated. In all of its properties it bears a great resemblance to the resins and essential oils. In fact it was found by Pronst that many of the common volatile oils yield a good proportion of camphor by simple spontaneous evapo-

ration, as for example, those of sage, rosemary, marjoram, lavender, &c.

A peculiar action appears to take place when alumina or clay and camphor are exposed to heat. La Grange ascertained that when made into a paste with water in the proportion of 6 of the former to 1 of the latter, and distilled from a retort into a receiver containing a little water, a quantity of carbonic acid and carburetted hydrogen gases, some camphoric acid and a peculiar oily fluid were the products. From 4 ounces of camphor managed in this way he obtained 12 drachms of oil of a golden yellow colour, of an aromatic odour similar to that of thyme, or rosemary, highly volatile and inflammable, soluble in alcohol and capable of combining with the alkalis.* It is called oil of camphor.

DCCLI. Camphor, though a production of nature, may be compounded by art. This curious fact was discovered by Kind, an apothecary at Eutin in Prussia, and verified by a committee of the society of apothecaries at Paris.

The process consists in transmitting muriatic acid gas through spirit of turpentine contained in Woulf's apparatus; the liquid gradually assumes a deep brown colour and a solid is deposited, which, when washed and sublimed in contact with charcoal powder and quicklime, condenses in white needle-form crystals having the taste, odour, and chemical properties of common camphor. Four pounds of oil of turpentine exposed to the action of the acid gas obtained from 4 pounds of common salt and 2 of sulphuric acid, produce 30 ounces of camphor.

If we except the small quantity of camphor employed in the composition of some of the varnishes, the use of camphor is confined to its medicinal exhibition. It acts upon the system as a narcotic.

* Nicholson's Journal, 4to, vol. ii. p. 93.

SECTION IX.

Of Tan or Tannin.

DCCLII. The name of tannin has been given to a substance which exists in the bark of some trees and in astringent vegetables, such as the bark of the oak and willow, and Aleppo galls. It was so called by the French chemists, from its property of combining with animal gelatine and forming leather.

Many processes have been proposed to obtain this principle in a state of purity, but none of them has succeeded in freeing it from other vegetable products, particularly from what has received the name of extract or extractive matter.

Tannin is usually procured from an infusion of Aleppo galls by precipitation with a saturated solution of carbonate of potash, or carbonate of ammonia, and washing the precipitate with a small proportion of water ; or with sulphuric acid, the precipitate being redissolved in water and the excess of acid saturated with an alkali.

DCCLIII. Tannin was found by Sir H. Davy in the extract of catechu, and by Dr. Bostock in the extract of Rhatan-y. The following, table drawn up by Sir H. Davy, shows the quantity of this principle afforded by 480 pounds of different barks ;* viz. of

	lbs.
Middle-sized Oak, cut in the spring	29
Spanish Chesnut	21
Leicester Willow, large size	33
Elm	13
Common Willow, large	11
Ash	16
Beech	10
Horse-chesnut	9
Sycamore	11
Lombardy Poplar	15

* Elements of Agricultural Chemistry, p. 89.

Birch	-	-	-	-	-	-	-	8
Hazel	-	-	-	-	-	-	-	14
Black Thorn	-	-	-	-	-	-	-	16
Coppice Oak	-	-	-	-	-	-	-	32
Oak, cut in autumn	-	-	-	-	-	-	-	21
Larch,	do.	-	-	-	-	-	-	8
White interior cortical layers of Oak Bark								72

On an average four or five pounds of good oak bark are required to form one pound of leather. Barks contain the greatest proportion of tannin at the time the buds begin to open—the smallest quantity in winter.

DCCLIV. Tannin obtained as above mentioned, is a substance of a brown colour, of a resinous appearance, brittle, uncrystallizable, and of an astringent taste. It is soluble in water forming a brown coloured solution, from which it may be precipitated by acids or alkalies. It is insoluble in alcohol.

On exposure to heat it swells up, becomes decomposed, leaves a large proportion of charcoal, and produces an acid liquor which gives to the salts of iron a black colour.*

Tannin is also separated from water by almost all the metallic oxides, and by the alkaline earths.

The appropriate test of tannin is glue, or animal gelatine. When a watery solution of this principle or of oak galls is added to a diluted solution of isinglass, a dull white precipitate is immediately formed, consisting of about 54 of gelatine and 46 of tannin. This compound is produced in the common process of tanning, and the result is leather. According to Dr. Duncan, the proportion of ingredients in this precipitate varies considerably, being influenced by the mode in which it is effected, and insolubility in water is by no means one of its characteristic properties.†

DCCLV. Another important property of tannin is that of combining with the peroxide of iron, and of forming a dark blue precipitate. It has no effect on the protoxide, or the

* Proust.

† Henry's Chemistry, 7th ed. Am. p. 486.

salts, into the composition of which it enters. The compound of tannin and the peroxide is decomposed by acids and the tannin is precipitated. It is in fact from this property arises the utility of galls and other astringent vegetables in the arts of dyeing and ink-making.

Tannin combines with starch and forms a compound which dissolves in water with difficulty.

According to the analysis of Berzelius, tannin is composed of

Carbon	-	-	-	51.160
Oxygen	-	-	-	44.654
Hydrogen	-	-	-	4.186
				<hr/>
				100.000*

DCCLVI. Tannin, though a natural production, may be formed by the art of the chemist. The discovery was partially made by Proust and Davy, but it was completed by Mr. Hatchett.

Having remarked the powerful effects produced by nitric acid on the resins, and the production of a substance which possessed peculiar properties, he was led to examine with greater care its action upon coal, bitumen, and charcoal. He found that tannin might be formed by repeatedly digesting nitric acid on charcoal, either animal or vegetable; by distilling it from any resinous substance; or by submitting the resins to the action of sulphuric acid. Thus an ounce of nitric acid was poured upon 100 grains of charcoal, and fresh portions were added to supply the place of that which was lost by digestion or decomposition, a solution was produced, which, on evaporation to dryness, yielded 114 grains of a substance exhibiting the characteristic properties of natural tannin.

Animal charcoal managed in the same way produces the

* Annals of Philosophy, vol. v. p. 182.

same result, and one portion of the skin of an animal may be thus made to convert the remainder into leather.*

The uses of natural tannin are numerous and important. It is the substance universally employed to convert the skins of animals into leather. The vegetable commonly employed for this purpose is oak bark; but there is a variety of other plants which afford it, and some in equal quantities; the sumach probably would answer the same end. It is also largely used in dyeing and making ink, in which arts it cooperates with gallic acid.

SECTION X.

Of Ulmin.

DCCLVII. Klaproth in 1804 described a substance which had exuded spontaneously from the elm, and its properties were more fully investigated in 1812 by Mr. Smithson and Dr. Thomson, the last of whom gave it the name of ulmin.†

This principle may be procured from a great variety of barks, according to Berzelius, by digesting the bark in alcohol, then in cold water, and finally in hot water holding in solution sub-carbonate of potash.

Ulm has a dark colour verging on black; it is insipid and inodorous, soluble in small proportion in water producing a pale brown solution, from which the ulmin is precipitated by acetate of lead and pernitrate of mercury in the form of brown flocks. It is precipitated from its alcoholic solution by the sulphates of iron and copper.

It is soluble in liquid alkalies, but the solution has not, like mucilage, any adhesive property. It is precipitated from them by the acids, of a buff colour, but is not affected by gelatine, tincture of galls, prussiate of potash, or alcohol. Ex-

* Philosophical Transactions for 1805 and 1806, or Nicholson's Journal, vols xii. and xiv.

† Philosophical Transactions for 1813. Annals of Philosophy, i. 23, and ii. pp. 11, 314, 395, 396. Thomson's System, vol. iv. p. 48. 5th ed.

posed to heat it swells up and takes fire, burning almost entirely away.

It is applied to no use.

SECTION XI.

Of the Colouring Matter of Vegetables.

DCCLVIII. The real nature of the matter which gives to the vegetable system its variety and beauty of colour is little known. Its modifications appear to be almost as numerous as the species of plants, and in many instances it is so fugitive that no accurate experiments can be executed upon it. It is very questionable, in fact, whether the substances which give colour to vegetables ought to be ranked with their other proximate principles, for they exhibit very different effects with reagents, their physical properties equally vary, and there appears to be but one connecting link of union, the power of communicating colour. The general properties of colouring matters are the following.

1. They are for the most part soluble in water. Thus log-wood and brazil-wood give to this liquid a red colour ; from the juices of the violet, the petals of the red rose, the daisy, blue hyacinth, litmus, red cabbage, and the raddish, it acquires a tinge of blue, and according to Mr. Smithson, the nature of the colouring matter is the same in all of these ; quer-citron, or the internal bark of the black oak, and weld, or the stalks of the *Reseda Luteola*, fustic, and sumach, produce yellow solutions, and turmeric affords one which is light brown. These solutions are not permanent ; in some cases the colouring matter assumes a dark colour and precipitates, in others it soon undergoes spontaneous decomposition and is destroyed.

2. The colouring matter in solution is affected by various reagents. The acids change all the blues to red, and the change of colour is permanent excepting in the case of car-

bonic acid. The alkalies, on the contrary, convert many of these blues to a green, and the same effect is produced by the alkaline earths, but when the latter are employed the green soon changes to a yellow. The purple colour of litmus, however, is not affected by the addition of the alkalies. Turmeric assumes by their action a deep tint of brown. These colours are very delicate tests of the presence both of acids and of alkalies.

3. A considerable affinity exists between the colouring matters and alumina, and the oxides of some of the metals. When alumina is boiled in a solution of this kind, the vegetable matter is transferred from the water which it leaves nearly colourless, and combines with the earths; and if solution of alum be added to a decoction of brazil-wood, and be then decomposed by an alkali, the alumina of the one and the colouring substance of the other will be precipitated in union. The same effect will be produced if solution of muriate of tin be substituted for that of the alum.

4. The substances which impart colour to plants have an affinity for various fibrous bodies, both animal and vegetable, such as wool, silk, cotton, and linen, and in some instances the latter may be permanently coloured by simple immersion in aqueous solutions of the former. The force of this mutual attraction varies with the nature of the fibrous matter, being exerted with greater energy by those which are of animal, than by such as are of vegetable origin; hence the effect is more durable with wool and silk than with linen and cotton. On this property depends the art of *Dyeing*. It happens, however, in most cases, that the cloth which has been dyed by immersion in a coloured solution, loses its tinge, and again becomes white by being washed with water, and some intermediate process is required to render the colour acquired by the article permanent. For this purpose the artist avails himself of the property of the colouring matter above mentioned, that of combining with the earths or metallic oxides, and thus forming a compound, the attraction of which for the

fibres of the cloth is greater than that of the vegetable matter alone. The substances thus used are called *Mordants*, and the principal of these are the acetate and super-sulphate of alumina, muriate of tin, sulphates of copper and of zinc, acetate of copper, orpiment, oxide of arsenic, &c. When the solutions of these salts are thickened by mucilage of gum arabic, they are applied to the cloth partially or wholly as circumstances require, and this being afterwards immersed in the coloured vegetable solution comes out permanently dyed. In this case, therefore, the attraction of the colouring matter for the cloth is aided by that of the salt, or mordant, and the combination is rendered more intimate and more durable.

5. In some cases the colouring matter appears to be in combination with resin, and then it is soluble only in alcohol or spirit of wine. The oils alone dissolve the colouring substance of alkanet root; and that of indigo is prepared for dyeing by solution in sulphuric acid. Light, as is well known, weakens the brilliancy, and in some instances, destroys the colours of these substances; the same effect is immediately produced by chlorine or oxy-muriatic gas.

6. The substances which are often employed as paints, are formed by the combination of the colouring matter with an earth or metallic oxide, and are known in commerce by the name of *Lakes*.

DCCLIX. The coloured juices of plants are likewise applicable to the purposes of the dyer, but they require some preparation before they can be rendered useful. The principal of these are woad, archil, litmus, annato, and rouge.

Woad is prepared from varieties of the *Isatis*, by powdering the plant, making it into balls with water, allowing them to ferment for a fortnight, and then reducing the mass to a coarse powder. It produces a blue colour, which however is inferior to that of indigo. *Archil* is obtained by exposing the powder of the *Lichen roccella* and *Lichen parellus*, to the action of lime and urine. Its colour is a beautiful but fugitive violet. It is used to brighten other colours, and when dissolv-

ed in alcohol, as a thermometric liquid. *Litmus* is the juice of the *Croton tinctorium*, with which linen rags are coloured, then reduced to a kind of paste, and formed into small squares. Its colour when dissolved in water is a delicate reddish purple, which changes to a full red on the addition of a minute portion of acid, and to a bluish purple by the action of an alkali. *Annota* or *Arnatto*, familiarly called *Otto*, is a kind of lake obtained from the seeds of the *Bixa orellana* by bruising and keeping them in water until a fermentation have taken place; it is then dried and formed into cakes or rolls of a red colour. It is not very soluble in water, for by infusion or decoction it produces a liquid which is turbid and of a yellowish red, but on the addition of an alkali its solubility is increased, and the solution assumes an orange colour. It is soluble in spirit of wine and the solution has a fine orange red colour. *Rouge* is the product of the *Carthamus tinctorius*, a plant growing on the banks of the Nile, where it is often cultivated for its beautiful red flowers. The petals of these flowers, after the juice is pressed out, are exposed on mats to the air and the dews of evening, but protected from the rays of the sun. They are thus slowly dried, and in that state carried to Europe, where the mass is known by the name of *safflower*. The mode in which rouge is prepared from it is kept a secret. *Hematin*. This name has been given by Chevreul to a substance obtained from logwood, by evaporating an aqueous solution of the colouring matter to dryness, digesting it with alcohol of the specific gravity of 0.837 for a day, filtering and concentrating the liquid by evaporation, adding a little water, evaporating a little, and setting the vessel aside. The crystals deposited are then to be washed with alcohol and dried. These crystals are small and brilliant, of a reddish white colour, and of a taste bitter, astringent, and acrid. They are more soluble in hot than cold water; in the first case the colour is red, in the second yellow, both of which are gradually destroyed by sulphurous acid. By the alkalies the colour of the solution is changed to a purplish

red, and when in great excess violet blue. Its solution assumes a yellow colour from sulphuretted hydrogen. The oxides of many of the metals combine with hematin and produce a compound of a violet blue colour.*

SECTION XII.

Of Morphia.

DCCLX. The singular fact is now established that there exists in opium a substance which has the essential characters of an alkali, but at the same time is composed of oxygen, hydrogen, and carbon. It was first obtained and described by Seguin in 1804, but his account of it was not published till 1814.† In 1803 Derosne gave some information respecting a peculiar crystallizable substance which he had procured from opium.‡ The greater part, however, of our knowledge on this subject we owe to the German chemist Surtürner.§ His mode of obtaining it was as follows. Eight ounces of powdered opium are to be digested in successive portions of warm distilled water, until the last comes off colourless. The liquid when sufficiently evaporated produces an extract, which, when aided by heat, forms a transparent solution with a large quantity of water. On the addition of liquid ammonia, a substance separates of a grayish white colour, and composed of small and irregular transparent crystals. These consist of morphia, mixed with extract and a peculiar acid which he called *meconic acid*. Diluted sulphuric acid is added in slight excess to the mass, the whole is then to be decomposed by ammonia, and the precipitate is to be treated with successive portions of ammonia, in order to remove the extract. It is afterwards to be washed with al-

* Annales de Chimie, lxxxi. 128, or Retrospect of Discoveries, vols. vi. and viii. p. 88 and 145.

† Annals of Philosophy, vol. xiii. p. 17.

‡ Annales de Chimie, xlv. 257.

§ Annales de Chimie et Physique, t. v. p. 21.

cohol, which removes the extractive matter, and the morphia which remains is then subjected to repeated solutions in, and crystallizations from alcohol, so that finally it appears in colourless and transparent prisms. Another method consists in rubbing the opium with 3 ounces of concentrated acetic acid and a little water, diluting the pap with 2 or 3 pounds of water and straining through a cloth. Precipitate by liquid ammonia, evaporate to $\frac{1}{4}$ or $\frac{1}{3}$ which will give a new product, reduce the precipitate to fine powder, and wash or digest it with a small quantity of alcohol. Dissolve in alcohol and crystallize.

DCCLXI. Morphia appears in the form of colourless crystals, consisting of double 4-sided pyramids whose bases are squares or triangles, or of prisms with trapezoidal bases. Morphia is soluble in 82 parts of boiling water, and the solution on cooling deposits regular, colourless, and transparent crystals. It is more soluble in alcohol and ether, requiring of the former at 92° 42 parts, and of the latter 8 parts; the liquids have a bitter and peculiar astringent taste, and when the saturated spirituous solutions are rubbed upon the skin they leave a red mark. All these solutions change the infusion of Brazil-wood to a violet, and the tinctures of rhubarb and turmeric to a brown colour.* It also restores the colour of blue vegetable infusions which have been rendered red by acids, and Robiquet has proved that this property is not owing to the presence of ammonia.

DCCLXII. Morphia combines with the acids and forms peculiar crystallizable salts.

Nitrate of morphia is in the form of needles, exhibiting a stellated appearance, or radiating from the centre, and soluble in $1\frac{1}{2}$ times its weight of distilled water. It is composed of nitric acid 20 parts, morphia 36, and water 44.

Muriate of morphia appears in needles or plumose crystals which require $10\frac{1}{2}$ times their weight of water for solution. The proportions of its constituents are 55 of muriatic acid. 41 of morphia, and 24 of water.

* Choulant. Annals of Philosophy, vol. xiii, p. 153.

Carbonate of morphia is in short prisms, soluble in 4 parts of water, and consists of 28 of carbonic acid, 22 of morphia, and 50 of water.

Sulphate of morphia crystallizes in prisms, soluble in twice their weight of water, and composed of 22 of sulphuric acid, 40 of morphia, and 38 of water.

Morphia likewise combines with the vegetable acids.

The number for morphia deduced from the composition of these salts, differ so much from each other, that no confidence can be placed in them. As calculated from the *sulphate* the representative number of this alkali will be 57.43.

With regard to the attraction of morphia for the acids, it appears to be inferior to that of all the other alkalies, for its compounds are decomposable by ammonia, and it is in its pure state incapable of forming saponaceous compounds with oils. It decomposes many of the metallic salts.

DCCLXIII. When exposed to heat morphia undergoes fusion and resembles melted sulphur, and like that substance it is capable of crystallizing on cooling. It is inflammable, and when heated in close vessels affords a residue of a black, resinous appearance, and peculiar odour. With sulphur it combines when heated, but the compound is not permanent, for decomposition takes place and sulphuretted hydrogen is evolved. It suffers no change when operated upon by voltaic electricity, even though it be in contact with mercury.

No analysis, so far as I know, has yet been made of morphia, but it is regarded as a ternary compound of oxygen, hydrogen, and carbon.

From the experiments of Sertürner, it appears to operate with great power upon the system as a narcotic, $1\frac{1}{2}$ grains of it having produced alarming symptoms in a young man 17 years of age.

SECTION XIII.

Of Acids.

DCCLXIV. The juices of many plants and their fruits are sour to the taste, and the researches of chemists have sufficiently demonstrated that the acids which produce this effect, though they are all composed of the same elements, differ in their properties, and their relations to other bodies, and require to be designated by different names. We shall now describe the most important of this class.

1. *Acetic Acid.*

DCCLXV. This important and useful substance has been found to exist in combination with different salifiable bases in the sap of different trees; it was obtained by Vauquelin from the juice of the *cicer arietinum*, and by Scheele from the *sambucus nigra*; it likewise exists in the *phoenix dactilifera*, the *gallium verum*, and the *rhus tiphinus*.* The great source of acetic acid is the fermentation of vegetable matter in that stage of it which has been called the *acetous*, and which terminates in the production of vinegar. We shall, therefore, defer the description of its properties until we arrive to the subject of the spontaneous decomposition of vegetables.

2. *Benzoic Acid.*

DCCLXVI. There is brought from the East Indies for medicinal purposes a concrete balsam, called *benzoin*, in the form of large masses composed of white and light brown pieces, friable, and of a faint and agreeable odour. When this balsam in coarse powder is exposed to heat in an earthen vessel or matrass having a cone of paper attached to its mouth, white vapours are formed, which condense into a solid upon the internal surface of the cone. This constitutes

* Thomson's Chemistry, vol. iv. p. 3, 5th ed.

benzoic acid. Much care is requisite in the operation, and the acid is apt to be burnt and thus acquire an empyreumatic odour. Several processes have been employed to obtain it without sublimation. Scheele digested benzoin in slaked lime and water, and afterwards decomposed the benzoate of lime by means of muriatic acid. Carbonate of soda was used by Gren, and the benzoic acid was separated by sulphuric acid; and Chaptal distilled over all the products of benzoin together, and obtained the acid free from the other ingredients by the use of boiling water. By these processes Mr. Brande procured the following quantities from 1 pound of benzein.

	Oz.	Dr.	Ser.	Grs.
Scheele's process. - - -	1	6	2	19
Chaptal's - - - .	2	0	0	0
By boiling benzoin in water - -	1	0	0	10
By Gren's and Gottling's processes	1	5	1	10

The same chemist found that 100 grains of benzoin yielded 14 of benzoic acid by sublimation.*

DCCLXVII. Benzoic acid as procured by heat is in the form of plates or needles, which are beautifully white and shining, soft, and unctuous to the feel. Its taste is warm and sweetish, followed by a slight degree of acid, its odour is peculiar and aromatic, a property which probably depends upon the presence of essential oil. Its specific gravity is 0.657. Exposed to heat it first melts and then assumes the form of vapour which is pungent and suffocating. At a high temperature it is decomposed and yields for the most part oil and carburetted hydrogen. It suffers no change on exposure to the air.

Benzoic acid is very sparingly soluble in cold water, but at a boiling heat that liquid takes up about $\frac{1}{23}$ of its weight, and the solution reddens the delicate vegetable blues. It is much more soluble in alcohol, for when cold the spirit will

* Nicholson's Journal, vol. x. p. 82.

dissolve one half its weight, and when hot an equal weight. It is dissolved likewise by the mineral acids, at least by the nitric and sulphuric, and precipitated from them by the addition of water.

DCCLXVIII. This acid combines with the salifiable bases and forms salts called *benzoates*.

The alkaline benzoates are crystallizable and soluble in water. Benzoate of ammonia is recommended by Berzelius as a good test of iron when it exists in the state of peroxide, and its solution contains no excess of acid. The benzoate of iron is of an orange colour and when dried contains $\frac{2.5}{100}$ of peroxide of iron. Benzoic acid likewise unites with the metallic oxides and forms with them salts which are of no great consequence.

This acid, according to the analysis of Berzelius, consists of 74.41 of carbon, 20.43 of oxygen, and 5.16 of hydrogen.

Benzoic acid constitutes an ingredient, though not an important one, of a few pharmaceutical preparations, and it is employed by the chemist as a test of iron.

3. Citric Acid.

DCCLXIX. Citric acid gives the sour taste to the juices of the orange and the lemon. It exists in combination with mucilage and water from which it may be freed by the process of Scheele, the juice being saturated with chalk, and the citrate of lime thus formed subsequently decomposed by sulphuric acid. The proportions, according to Proust, are 4 parts of chalk, and 94 of lemon juice, which produce $7\frac{1}{2}$ of citrate of lime, and require for their decomposition 20 parts of a mixture of 1 part of sulphuric acid with 3 parts of water. After the addition of the diluted acid to the citrate of lime, the liquid mass is boiled for a short time in a glass vessel, then filtered, and evaporated to the consistence of a syrup; if any sulphate of lime be deposited during the evaporation it is to be separated. Crystals of citric acid form as the liquid cools.

DCCLXX. Citric acid is in the form of transparent rhomboidal prisms or octaedrons, of an exceedingly sour taste, capable of reddening vegetable blues, and unalterable in the air. It contains water, which, according to Berzelius, exists in the ratio of 17 to 83 of acid.

Exposed to heat it first melts, then exhales a pungent vapour, and produces a small portion of charcoal. When distilled in close vessels part of it sublimes, and the rest is decomposed, forming the various compounds of oxygen, hydrogen, and carbon, and leaving the charcoal in the retort.

Citric acid is exceedingly soluble in water, requiring at the temperature of 60° only $\frac{3}{4}$ of its weight of that liquid for its solution; at 212° it is dissolved in the proportion of twice the weight of the water; hence it is not very easy to obtain a large product of well defined crystals by one operation.

DCCLXXI. This acid unites with the salifiable bases and constitutes salts which are called *citrates*.

Citrate of ammonia crystallizes in long and slender prisms, which have a cool, saline taste, are very soluble in water, and decomposable by a moderate heat. It consists, according to Vanquelin, of 62 of citric acid, and 38 of ammonia.

Citrate of potash, produced by saturating the acid with potash, is of difficult crystallization, is very soluble and deliquescent, and has a taste mildly saline. It is composed of 55.55 of acid and 44.45 of potash.

Citrate of soda. Formed as the preceding—crystals 6-sided prisms—taste saline and cooling—soluble in water, and slightly efflorescent—decomposed by heat—contains 60 parts of acid and 40 of soda. Citric acid combines with lime, magnesia, barytes, and strontian, producing peculiar saline compounds.

It likewise unites with the metallic oxides.

DCCLXXII. According to Dizé, solutions of acetates of magnesia, lime, and alumina, of muriates of barytes, lime, alumina, and magnesia, and of nitrates and sulphates of the same substances, do not undergo any change by the presence

of citric acid. The muriates and nitrates of zinc, the sulphate, nitrate, muriate, and acetate of copper, and the nitrate of lead, are not decomposed, but the acetate of lead is immediately decomposed and precipitated in the form of a white powder. The nitrate and acetate of mercury are likewise decomposed, and the mercurial citrate which falls down is a flaky salt of a brickdust colour, more or less red. This acid gives a green tinge to the solutions of acetate and sulphate of iron.*

Citric acid, analyzed by chlorate of potash, afforded M. M. Gay-Lussac and Thenard 59.859 of oxygen, 33.811 of carbon, and 6.330 of hydrogen.† Berzelius states the proportions at 54.831 of oxygen, 41.869 of carbon, and 3.800 of hydrogen.‡

DCCLXXIII. The uses of citric acid are not numerous. It is used as a discharger of colour in calico-printing, in consequence of its affinity for the oxides of iron. In the form of lemon juice it is employed as an effectual preventive of, or remedy for the scurvy; and Dizé observes that an agreeable lemonade may be formed by dissolving 40 grains of citric acid in a pint of water, with the addition of pure sugar, or of “oleo-saccharum,” which is sugar rubbed with a lemon until it has imbibed some of its essential oil. The oleo-saccharum thus obtained may be rubbed in a mortar with sugar, and after having been dried in a gentle heat, may be preserved in close phials. This method of procuring the flavour of lemons at all times is preferable to employing the volatile oil obtained by distillation, which is much more acrid and much less agreeable to the taste.

The salt which is sold in the shops by the name of essential salt of lemons, and which is used to remove iron stains from cloth, is not procured from the juice of that fruit. It is a super-oxalate of potash.

* Nicholson's Journal, 4to, vol. ii. p. 43.

† *Rechères Physico-Chimiques*, ii. 307.

‡ *Annals of Philosophy*, v. 93.

4. *Gallic Acid.*

DCCLXXIV. Gallic acid has been found to exist in a considerable number of vegetables, and for the most part resides in the bark. The substance from which it is always obtained by the chemist is a peculiar excrescence which grows on the leaves of a species of oak, and which is supposed to be produced by the puncture of an insect. These excrescences, which are nearly round, of the size of a pigeon's egg, of a brown colour, and nodulated surface, are known in commerce by the name of nut-galls or Aleppo galls, whence is derived the term by which the acid is designated.

Different processes have been followed to obtain gallic acid. If a saturated infusion of galls be exposed for a long time to the air, it becomes mouldy, a sediment is formed, which when washed with cold water, and afterwards dissolved in boiling water, filtered, and evaporated, yields gallic acid in the form of a grayish powder of a sandy appearance. This method was first practised by Scheele. It is now thought best to dissolve the mass after washing in alcohol, and then evaporate.

The acid may likewise be obtained by sublimation from powdered galls. The powder is put into a large glass retort and its temperature gradually raised. The acid rises in vapour and condenses in prisms on the internal surface of the neck. But much caution is requisite in conducting the process, otherwise the whole product may be lost by the temperature rising too high.

Other processes have been given to procure this acid by Fiedler, and Richter.

DCCLXXV. When pure, gallic acid is in the form of white and brilliant prisms or needle-form crystals, sometimes in plates or octoedrons, of an acid and astringent taste, soluble in 24 parts of cold water, and 3 of boiling water; it is still more soluble in alcohol. These solutions are sour, they redden vegetable blues, and effervesce with alkaline carbon-

ates. On exposure to heat it melts, gives out a peculiar odour, and sublimes without decomposition. In a higher heat its elements take on new arrangements. If heated strongly and suddenly in the open air, it takes fire, burns with flame, and exhales an aromatic odour. By the action of nitric acid it is converted into oxalic acid.

DCCLXXVI. Gallic acid combines with the salifiable bases. The alkaline *gallates* have not been particularly examined ; they are soluble in water. The gallates of the earths are insoluble. Gallic acid precipitates many of the metals from their solutions, and a variety of colours is produced. From muriate of gold the precipitate is brown ; from nitrate of silver, gray ; from solution of mercury, orange-yellow ; from copper, brown ; from acetate of lead, white ; and from nitrate of bismuth, lemon-yellow.

The most important of its metallic combinations is with peroxide of iron, producing a precipitate of a very deep blue, which is of greater tenuity, and remains longer suspended in water than that from tannin. Writing ink, therefore, is a mixture of gallate, and tannate of iron, suspended in water by the medium of gum ; and hence we see the advantage of making use of galls for this purpose, which contain both tannin and gallic acid. The iron must be in the state of peroxide, for the protoxide produces but little if any change of colour with gallic acid.

5. *Hydro-cyanic, or Prussic Acid.*

DCCLXXVII. The properties of this acid have been already described at page 462 of the first volume. It is prepared by the chemist by the medium of potash and animal matter, but it has been sufficiently proved that it exists ready formed in a variety of plants. It may be obtained from the distilled waters of the peach-blossom, of the leaves of the lauro-cerasus, and the kernel of the bitter almond, by the addition of potash, which forms a prussiate or hydro-cyanite,

capable of producing prussian blue with the peroxide of iron. It is supposed that most if not all of the bitter kernels contain this acid.

6. *Malic Acid.*

DCCLXXVIII. This acid derives its name from the apple, the juice of this fruit, particularly while unripe, having been proved by Scheele to owe its sour taste to the presence of a peculiar acid. It likewise exists, together with citric acid, in the juices of lemons, and of most of the berries. Besides the malic acid, Mr. Donovan has stated that another acid is found in some of these juices, and in consequence of being procured with ease from the *Sorbus*, or *Pyrus aucuparia*, he gave it the name of *Sorbic acid*. The properties of these two acids and their compounds very nearly resemble each other, and the researches of Braconnot are quoted by Dr. Thomson as leaving no doubt whatever that the malic acid of Scheele, when brought to a state of purity, is identical with the sorbic acid of Mr. Donovan.* The process of the latter however furnishes it in a much purer state than that of Scheele.

Malic acid is also formed together with the oxalic during the action of nitric acid on sugar.

Scheele's method of obtaining this acid was to saturate the juice of unripe apples with chalk, and to decompose the malate of lime by sulphuric acid. Mr. Donovan's consists in mixing solution of acetate of lead with the juice of the berries of the sorbus, the precipitate is washed on a filtre with cold water, and afterwards with a large quantity of boiling water, which, on being allowed to stand for some hours, becomes turbid and deposits shining and beautiful crystals. More crystals may be obtained from the mass on the filtre by boiling it with an excess of sulphuric acid diluted with water, adding to the filtered liquid acetate of lead, and treating the precipitate as before. The crystals are to be pu-

* Annals of Philosophy, vol. xiii. li.

rified by boiling them with 2.3 times their weight of sulphuric acid of the specific gravity of 1.090, adding water occasionally and constantly agitating the liquid with a glass rod. When the liquid is decanted, a stream of sulphuretted hydrogen is to be passed through it, it is then filtered, boiled to separate the superfluous sulphuretted hydrogen, and it then constitutes a solution of sorbic, or malic acid.

According to Braconnot, malic acid when pure is colourless, soluble in water, alcohol, and ether, and susceptible of crystallization. When heated it sublimes, but the sublimed crystals possess characters somewhat different from those of malic acid before it has been exposed to heat. The acid, thus altered, has been called *pyro-malic acid*.

Malates of potash and soda are incapable of crystallizing, but crystals may be readily formed from malates of magnesia and zinc. It does not precipitate nitrate of lime, silver, or mercury, but forms a white precipitate with acetate of lead, which is soluble in distilled vinegar, and in boiling water. It produces no sensible change when dropped into lime, or barytes-water.

If sorbic acid be identical with malic acid, the reader will find many of the malates described by Braconnot and Vauquelin, under the name of sorbates, in the 12th vol. of the *Annals of Philosophy*, p. 290, and 293.

7. Oxalic Acid.

DCCLXXIX. This interesting acid takes its name from the *oxalis acetosella*, or *sorrel*, in which it exists in combination with potash in excess, constituting a quadroxalate. It is found likewise in the juices of several other plants. But for the purposes of the chemist it is procured from sugar and nitric acid.

The process consists in adding to one ounce of powdered loaf-sugar contained in a tubulated retort, connected with a large globular receiver, 3 ounces of nitrous acid, effervescence

takes place, and abundance of red fumes is disengaged, the liquid is then boiled, by which more fumes will be extricated, and it acquires a dark brown colour. Three ounces more of nitrous acid are then poured into the vessel and the boiling is repeated until the vapours have ceased to be formed. The remaining liquid is then poured out, and as it cools oxalic acid will crystallize. The product is small, amounting only to 109 grains; but if 2 ounces of nitrous acid be added to the residue and be treated as before, 43 grains more of acid may be obtained.

M. Lassaigne has shown that the *Rheumatic acid* of Mr. Donovan is the oxalic.

Oxalic acid, procured by the above method and purified by frequent solution and crystallization, is in the form of small, white, and brilliant 4-sided prisms with dihedral summits, exceedingly sour to the taste, capable of reddening vegetable blue, and of combining with salifiable bases, forming salts, which are called *oxalates*. These crystals contain, according to Berzelius, nearly half their weight of water, being composed of 52 of real acid, and 48 of water. Hence on exposure to heat, the texture of the crystal is destroyed. Other chemists have stated the proportion of water to be much less.

Oxalic acid is soluble in water, requiring for its solution in that liquid when cold twice its weight, and when hot an equal weight. It is likewise dissolved by alcohol or spirit of wine. Bauhof mixed 1 part crystallized acid with 8 parts of absolute alcohol, and repeatedly distilled the liquid until the former disappeared, and an oily looking fluid was obtained with the following properties. Its colour was brownish yellow, its odour similar to that of the *sweet oil of wine*, and its taste, nauseous, bitter, and somewhat metallic. In specific gravity it was superior to water, and fell into that liquid like oil drops, but mixed with it by agitation. It first reddened vegetable blues, but was deprived of that property by agitation with carbonate of lime. It was soluble in spirit of wine, in boiling muriatic acid, and concentrated sulphuric

acid. Mixed with water and distilled in a retort it was decomposed, an acidulous water passed over, and there remained an acid liquid which deposited oxalic acid. This oil and its alcoholic solution were decomposed by caustic ammonia and a white precipitate was formed, which was inferred to be a compound of the oily liquid and ammonia; it was destitute of taste and odour, was insoluble in water, but volatile without suffering decomposition on exposure to heat. It was not decomposed by being boiled with potash or soda.*

Oxalic acid is dissolved by some of the acids, and decomposed by others; of the former are muriatic and acetic, and of the latter nitric and sulphuric acids.

DCCLXXX. This acid unites with the salifiable bases and forms peculiar salts.

Oxalate of ammonia, prepared by saturating an aqueous solution of oxalic acid with carbonate of ammonia, and subsequent evaporation, is in the form of 4-sided prisms terminated by dihedral summits, of a saline, bitterish taste, soluble in 22 parts of cold water, but insoluble in alcohol. It consists according to Berard of 72.34 of acid, and 27.66 of ammonia. It is decomposed by heat, and yields carbonate of ammonia and charcoal, a portion of the acid being at the same time volatilized.

A binoxalate of ammonia may likewise be formed, which contains twice as much acid as the oxalate.

Oxalate of potash. The proximate elements of this salt unite in no less than three different proportions, producing oxalate, binoxalate and quadroxalate of potash.

1. *Oxalate*. When potash is dissolved in solution of oxalic acid, a neutral compound forms, which in consequence of its solubility, instead of crystallizing, becomes gelatinous by evaporation. If there be a slight excess of acid or base it then crystallizes with ease. A solution of 2 parts of carbonate of potash to 1 of oxalic acid forms 6-sided prisms. The neutral oxalate, according to Dr. Thomson, crystallizes in flat

* Annals of Philosophy, xii. 23.

rhomboids, with bevelled edges and di-hedral summits. Its taste is cooling and bitter, and it is slightly deliquescent. It is soluble in rather more than twice its weight of water at 50°.

2. *Binoxalate, or super-oxalate.* This salt may be formed by dropping solution of potash into a strong solution of oxalic acid, or of the neutral oxalate. It crystallizes in opaque parallelopipedons, is sour to the taste, capable of reddening vegetable blues, soluble in eight times its weight of boiling water, and forming a permanent solution. It is decomposed by the acids with difficulty. It unites with most of the alkalis and earths and forms with them triple compounds. It is decomposed by heat.

This salt, as has been remarked, exists in the wood-sorrel; it is likewise found in the *rumex acetosa*.

3. *Quadroxalate.* This salt was discovered by Dr. Wollaston. It may be formed by decomposing binoxalate of potash by nitric or muriatic acid, which takes half the potash from the acid, and leaves a salt containing 4 times as much oxalic acid as the neutral oxalate. It is less soluble than the other varieties.

Several analyses of these salts, or at least of the two first, have been executed. As Dr. Wollaston has proved that the last contains four proportions of acid to one of base, while the binoxalate consists of 2 of the former to 1 of the latter,* their composition theoretically may be gained by the analysis of the oxalate. Vogel states the composition of oxalate of potash at 100 of acid and 132.55 of base. Hence the quadroxalate will consist of 75.12 of acid and 24.88 of base; the binoxalate of 60.18 of acid, and 39.82 of base; and the oxalate of 43 of acid to 57 of base, very nearly.

Oxalate of soda appears in the form of crystalline grains which give a green tinge to vegetable blues and are soluble in hot water; they are composed of 53 of acid, and 47 of

* Nicholson's Journal, xxi. 164.

base.* A super or binoxalate of soda may likewise be formed which contains double the proportion of acid.

Oxalate of barytes, produced by decomposing a salt of barytes by an oxalate, is in small crystalline grains, insipid and sparingly soluble in water; it consists of from 58 to 62 of barytes and from 38 to 42 of acid.

The binoxalate may be produced by boiling oxalic acid in solution of muriate of barytes. Oxalic acid likewise combines with strontian.

Oxalate of lime. The affinity of oxalic acid for lime is very powerful, and it is capable of taking that base from every other acid. Hence the mode of forming it is to decompose a soluble salt of lime, either by solution of oxalic acid alone, or by solution of an oxalate, particularly of ammonia. The precipitate is in the form of a white insoluble powder, which gives a green colour to vegetable blues. It is dissolved but not decomposed by the acids, but on exposure to heat the elements of the acid assume new arrangements and the composition of the salt is changed. Its composition when dry may be stated at 56 parts of acid, and 44 of base.

Oxalate of magnesia is a white powder, insipid, inodorous, and insoluble in water; composed, according to Bergman, of 65 of acid and 35 of magnesia.

Oxalic acid likewise combines with many of the metallic oxides and forms salts.

Exposed to heat this acid first undergoes aqueous fusion, it then boils, and is afterwards decomposed, and the products of its decomposition are water, carbonic acid, carbonic oxide, and carburetted hydrogen gases, and charcoal. Hence oxalic acid is composed of oxygen, hydrogen, and carbon. Great pains have been taken by chemists to determine the relative proportions of these elements, and the analysis has been effected in three ways; first, by the decomposition of the acid by heat, and determining the proportion of the sub-

* Thomson's Chemistry, ii. 451.

stances evolved; secondly, by burning it in contact with chlorate of potash; and thirdly, by decomposing some of the oxalates by heat. According to M. M. Gay-Lussac and Thenard this acid is composed of

Carbon	-	-	-	-	26.566
Oxygen	-	-	-	-	70.689
Hydrogen	-	-	-	-	2.745
					<hr/>
					100.000

or of

Carbon	-	-	-	-	26.566
Oxygen and hydrogen in the propor-	}				22.872
tion to form water					
Oxygen, in excess	-	-	-	-	50.562
					<hr/>
					100.000*

By Berzelius its composition is stated at

Carbon	-	-	-	-	33.222
Oxygen	-	-	-	-	66.534
Hydrogen	-	-	-	-	0.244
					<hr/>
					100.000†

Dr. Thomson assigns as the proportions

Oxygen	-	-	-	-	64.00
Carbon	-	-	-	-	32.00
Hydrogen	-	-	-	-	4.00‡

Oxalic acid is employed by the chemists as a test of the presence of lime, and its power in this respect is increased by previously combining it with ammonia. The oxalate of lime however is soluble in nitric and muriatic acids, and hence if either of these exists in an uncombined form in the liquid to be examined, it must be neutralized by an alkali.

* Recherches, t. ii. p. 299. † Annals of Philosophy, vol. v. p. 99.

‡ System of Chemistry, ii. p. 155, 5th ed.

The delicacy of this test is such that it will detect 1 grain of lime dissolved in 88 ounces troy, or more than 7 pounds of water.

Salt of sorrel, which has been proved by Berard to be a quadroxalate, is used to remove stains upon cloth, produced by writing ink. A few grains of it are placed upon the spot and water is slowly added until the salt is dissolved and the solution has passed through the cloth; the excess of acid unites with the peroxide of iron, the cause of the stain, and may be removed by washing. Pure oxalic acid produces the same effect in a shorter time, and in neither case is the texture of the cloth injured.

Oxalic acid, when taken into the stomach in any quantity, operates as a poison, probably by producing inflammation, erosion, or gangrene in that organ. Cases are on record in which from half an ounce to one ounce of this acid, which had been taken by mistake for common salts, occasioned death.

8. *Tartaric Acid.*

DCCLXXXI. There is a peculiar salt deposited from the weak bodied wines of the south of France, which is known in commerce by the name of *tartar*, and when purified, by that of *cream of tartar*. It is a compound of tartaric acid in excess with potash, or a bi-tartrate of potash. From this salt the acid may be procured by the following process.

Diffuse 6 parts of finely powdered chalk in 86 parts by weight of boiling water, and add to the liquid by small portions at a time, as much cream of tartar as is sufficient to neutralize the excess of acid in the salt, which is known by the cessation of effervescence. The base of the chalk unites with the excess of acid, and forms an insoluble tartrate of lime, which, after being washed with water, is to be put into a glass vessel, and decomposed by 6 parts of sulphuric acid, diluted with half its weight of water. The whole is to be digested in a sand bath with frequent agitation for 12 hours.

Sulphate of lime is formed and tartaric acid disengaged. When acetate of lead is added to this liquid, the precipitate, if there be no excess of sulphuric acid, is soluble in nitric acid; if that acid be in considerable excess, the greater part, but not the whole, should be saturated by the addition of chalk, or of tartrate of lime. The filtered liquid, on due evaporation, will yield crystals of tartaric acid. The neutral tartrate of potash which remains dissolved in the first liquid may then be decomposed by muriate of lime, and a tartrate of lime formed, from which the tartaric acid may be procured by the above described method.

When one proportion only of tartaric acid is obtained, the amount of the product is equal to $\frac{1}{4}$ or $\frac{1}{5}$ of the weight of the cream of tartar, but by means of muriate of lime the whole of the acid may be abstracted from the potash.

Dr. Henry recommends that 100 of cream of tartar should be intimately mixed by trituration with 50 parts of chalk, and the mixture be added to 8 or 10 parts of boiling water.

Pure lime decomposes the whole of this salt, but as Vauquelin has found, the potash disengaged dissolves a portion of the tartrate of lime, and lessens the amount of the product.

Tartaric acid in consequence of its solubility is not very easily obtained regularly crystallized; its form is that of tables, pyramids, or prisms, according to the extent to which the evaporation has been carried. Its taste is exceedingly sour, it effervesces with alkaline carbonates, and gives a red tinge to vegetable blues. According to Berzelius, the crystals consist of 88.75 parts of real acid, and 11.25 of water.

This acid is very soluble in water.

Exposed to heat it first melts, then becomes dry, and if distilled in close vessels yields an acid liquid, called by Fourcroy and Vauquelin pyro-tartaric acid, and carburetted hydrogen. According to Gay-Lussac and Thenard it consists of

Carbon	-	-	-	-	24.050
Oxygen	-	-	-	-	69.321
Hydrogen	-	-	-	-	6.629
					<hr/>
					100.000*

The proportions assigned by Berzelius differ essentially from the above. He makes the acid to be composed of

Carbon	-	-	-	-	36.167
Oxygen	-	-	-	-	59.882
Hydrogen	-	-	-	-	3.951
					<hr/>
					100.000†

Tartaric acid unites with the salifiable bases frequently in two proportions, and forms peculiar salts.

Tartrate of potash. Soluble tartar. This neutral tartrate may be easily prepared by dissolving cream of tartar in boiling water, adding to the solution carbonate of potash until effervescence ceases, and evaporating to a sufficient degree. It crystallizes in flat, 4-sided prisms with dihedral summits, of a bitterish taste, soluble in about an equal weight of cold water, and decomposable by heat. In round numbers it is composed of 42 parts of potash and 58 of acid.

Bi-tartrate. Super-tartrate. This salt has been known and used both in medicine and the arts. It is procured crystallized from the aqueous solution of cream of tartar. It is difficult to determine the species of crystal belonging to this salt, but Dr. Wollaston states it to be a prism terminated by dihedral summits. The crystal is translucent, white, brittle, acid to the taste, and hard. It is soluble in about 60 parts of cold and 30 of boiling water; on long standing the salt in this solution becomes decomposed and its elements assume new arrangements.

On exposure to heat the bi-tartrate of potash melts, then blackens and is decomposed, carbonic acid and carburetted

* *Rechères*, t. ii. p. 302.

† *Annals of Philosophy*, v. 96.

hydrogen gases, with empyreumatic oil are formed, and the residue consists of carbonate of potash mixed with charcoal. Hence was derived the name of *salt of tartar*, applied by the earlier chemists to this salt of potash.

The bi-tartrate contains twice as much acid as the tartrate.

From the insolubility of this salt, potash may be employed as a test of the presence of tartaric acid, and tartaric acid may be used to distinguish potash from soda, for when solution of this acid is added to a strong solution of potash, minute crystals of the bi-tartrate immediately form in the liquid.

The excess of acid in this salt may be saturated with other bases, and triple salts be thus formed which exhibit properties varying essentially from those of the bi-tartrate. Thus by saturating it with soda, a tartrate of potash and soda may be produced, which crystallizes in large and transparent prisms, having a saline taste, and being very soluble in water. It was formerly known in medicine by the names of *Sal de Seignette* and *Rochelle salts*.

When the excess of acid in cream of tartar is neutralized by ammonia, a salt is formed which crystallizes in prisms, is very soluble in water, has a saline taste, and is decomposable by heat with facility.

Triple salts may likewise be produced by the combination of metallic oxides with the free tartaric acid in the bi-tartrate. The properties of the most important of these, the tartrate of potash and antimony, or tartar-emetic, have been already described.

Pearl-white, a substance used as a paint for the face, is formed by adding solutions of bi-tartrate of potash, and nitrate of bismuth together, a tartrate of bismuth which is white and insoluble, being thus precipitated.

The other tartrates are of little consequence. It was once supposed by chemists that there existed an acid with less oxygen in it than in tartaric acid, and they gave to it the name of *tartareous acid*, and to its compounds with bases that of

tartrites, terms which are still employed in medicine. But it is now known that there is but one acid of tartar.

The uses of tartaric acid are very limited. It is now principally employed in the formation of the powders used to produce a liquid analogous to soda-water. Powders of this acid, and of carbonate of soda, or more frequently of bi-carbonate of potash, are put up in separate papers, and when they are to be used are diffused in water, by which a brisk effervescence is produced.

Such are the general properties of the most important of the vegetable acids. There exist others which are found only in small quantities, and as yet are applied to no uses, and will therefore require merely to be noticed.

DCCLXXXII. *Boletic acid.* Braconnot obtained this acid from the juice of the *boletus pseudo igniarius*, by digesting the matter, left after evaporation, in alcohol, removing the solution, and dissolving the residue in hot water. Nitrate of lead was then added, and the precipitate, after being washed, was decomposed by sulphuretted hydrogen. Two acids were thus obtained, the one phosphoric acid and the other the *boletic*. This was dissolved in alcohol and crystallized. Its form is a 4-sided prism, but imperfect, its taste is slightly acid, it reddens vegetable blues, and combines with bases forming *boletates*. It is not very soluble in water, requiring of that liquid at 60° no less than 180 parts; it dissolves in 45 of alcohol.

Boletic acid may be sublimed by heat, and its vapour is acrid and irritating.

DCCLXXXIII. *Suberic acid.* The substance so called from *suber*, the Latin name of cork, was first observed by Brugnatelli, and more fully investigated by La Grange and Chevreul.

It is obtained by the action of diluted nitric acid on cork, when aided by heat. The process may be found in Nicholson's Journal, vol. 23.

It is a white, uncrystallizable substance, of a slight acid taste, but irritating to the throat. It is deliquescent in a hu-

mid atmosphere. It is volatile at a moderate heat, and in condensing crystallizes in needles.

Suberic acid combines with some of the bases, and with the alkalies forms crystallizable salts. According to La Grange, it differs from citric acid in not crystallizing; from the gallic acid, by producing no black precipitate with peroxide of iron; from malic, by its solid form; from tartaric, by its volatility; and from oxalic, by its want of action with sulphate of copper.

Camphoric acid, obtained by the action of nitric acid on camphor, is a white, crystalline substance of an acid and bitter taste, and an odour similar to that of saffron. It is sparingly soluble in water, but dissolves in rather less than its weight of alcohol. Exposed to heat it melts and then sublimes. It is soluble in the mineral acids, and combines with salifiable bases.

Moroxylic acid, so called by Klaproth from having been obtained from a salt which exuded from the *Morus Alba*, or white mulberry of Sicily. The mode of decomposing this salt and of procuring the acid, is detailed in the 7th vol. of Nicholson's Journal. It has the taste of acid of *amber*, is not deliquescent, dissolves readily in alcohol, but does not precipitate metallic solutions. It sublimes on exposure to heat.

Meconic acid. Surtürner first obtained this acid from opium in his attempts to separate morphia. It may be procured by the following method. Into the liquid which remains after the separation of morphia, and which contains neither that substance, nor any excess of ammonia, pour solution of muriate of barytes until it cease to produce a precipitate. The meconiate of barytes thus formed is to be triturated in a mortar with an equal weight of vitreous boracic acid. The mixture being put into a small glass flask and surrounded with sand in a sand-bath, heat is to be applied until the meconic acid is sublimed.

It is in the form of fine white scales or plates, sour to the taste, with a degree of bitterness, soluble in water, alcohol,

and ether, capable of reddening vegetable blues, and of combining with salifiable bases. It changes the solutions of iron to a cherry-red colour, and when they are heated the iron is precipitated in the form of protoxide.

Meconiate of potash is in 4-sided tables, soluble in twice their weight of water.

Meconiate of soda crystallizes in soft prisms, and meconiate of ammonia in star-formed needles.

Meconiate of lime crystallizes in prisms.*

Lampic acid. Mr. Faraday ascertained that when heated platinum was made to act upon the vapour of ether, in Sir H. Davy's experiment, as detailed in volume 1st of this work, a peculiar acid was formed, some of the properties of which he investigated. Mr. Daniell succeeded in obtaining it in larger quantities by employing sulphuric ether instead of alcohol in the *lamp without flame*, by putting it into the head of an alembic and keeping it in constant operation for several weeks. The product was a liquid to which he gave the name of *Lampic acid*. He thinks it is the same, whether obtained from alcohol, ether, or oil of turpentine. About a pint and a half was procured in this way by the combustion of ether. It was a colourless and transparent liquid, of an intensely acid taste and pungent odour, irritating to the lungs, and acting upon the mucous membrane like chlorine. Its specific gravity varied from 1.000 to 1.008. When evaporated carefully it allowed a quantity of alcohol to escape, and the specific gravity then increased to 1.015. It produced the usual effects of acids on vegetable colours, and decomposed all the carbonates.

All the *lampates* are deliquescent salts. Lampate of ammonia is very volatile, and evaporates at a temperature below 212° . While burning, it emits a disagreeable odour similar to that of animal substances. Gold, silver, and platinum are reduced to the metallic state by this acid. When analyzed by the method of Gay-Lussac and Thenard, viz.

* Choulant. *Annals of Philosophy*, vol. xiii. p. 230.

by combustion with chlorate of potash, Mr. Daniell found the constituents of this acid to be

Carbon	-	-	-	-	40.7
Hydrogen	-	-	-	-	7.7
Water	-	-	-	-	51.6
					<hr/>
					100.0

or

1 atom carbon	-	-	-	= 0.75
2 atoms hydrogen	-	-		= 0.25
1 atom oxygen	-	-	-	= 1.00
				<hr/>
				2.00

SECTION XIV.

Of Lignin, or Ligneous Fibre.

DCCLXXXIV. The ligneous fibres are to the vegetable, what the bones are to the animal system. They give support to the vessels which circulate the juices and contribute to the growth of the plant. They exist apparently in every part, at least in all those portions which are vascular, and constitute what is commonly called wood.

It may be obtained pure by frequent maceration of a portion of wood in water and alcohol, the former dissolving and removing the mucilaginous and extractive matter, and the latter the resin or essential oil.

Wood is of a fibrous structure, the fibres being parallel to each other or interlaced, white, destitute of taste and odour, and insoluble in water and alcohol. It dissolves slowly and without alteration when aided by heat in weak solutions of the alkalis, but is decomposed by them when strong. Put into sulphuric acid it is decomposed and charcoal disengaged, which tinges the liquid black. Nitric acid converts it into some of the vegetable acids.

Heated sufficiently out of contact with the air, or rather where the air is admitted in small proportion, it is decomposed, various substances are disengaged, and the basis which remains is charcoal. When distilled in close vessels it yields water, an acid liquid of a pungent smell and yellow colour, empyreumatic oil, carbonic acid, and carburetted hydrogen gases, a small portion of ammonia, and leaves a quantity of charcoal.

According to the analysis of Gay-Lussac and Thenard, the wood of the oak consists of

Carbon	-	-	-	-	52.53
Oxygen	-	-	-	-	41.78
Hydrogen	-	-	-	-	5.69
					<hr/>
					100.00

The woody fibre of the beech was composed of

Carbon	-	-	-	-	51.45
Oxygen	-	-	-	-	42.73
Hydrogen	-	-	-	-	5.82
					<hr/>
					100.00*

The distillation of wood produces a considerable proportion of an acid liquid which was for some time supposed to be of a peculiar nature, and was called the *pyro-ligneous acid*. It has since been proved to be vinegar, or diluted acetic acid, disguised by the presence of empyreumatic oil. "Very good vinegar is now made from wood both in London and Glasgow. Animal charcoal is probably employed to remove the empyreumatic oil."†



The vegetable principles hitherto described appear to be ternary compounds of oxygen, hydrogen, and carbon. We shall now advert to those which are quaternary, and these are Extract, Gluten, Albumen, Caoutchouc, Indigo, and Birdlime.

* *Rechères Physico-Chimiques*, t. ii. p. 294.

† Thomson's System, vol. iv. p. 184, *note*, 5th ed.

SECTION XV.

Of Extract, or Extractive Matter.

DCCLXXXV. The claims of this substance to be considered as a distinct proximate principle of plants are very doubtful. Its characters as obtained from different vegetables are not the same, and in many instances they appear to graduate into those of principles which are easily recognized and are well specified. In chemistry the term *extract* has a different meaning from that which is assigned to it in pharmacy, but in fact most if not all of the medicinal extracts contain this principle.

An idea may be obtained of what is meant by extract from the properties presented by a substance procured from English saffron, by making an infusion in hot water of this plant and evaporating to dryness at a moderate temperature.

It is always of a brown colour more or less deep, cohesive, and of a taste similar in a great measure to that of the vegetable from which it is obtained.

It is soluble both in water and alcohol, but insoluble in ether; its solutions are coloured. When the aqueous solution is long boiled, it assumes a darker colour, and the extract at length separates in an insoluble state, a change which has been inferred to depend upon the absorption of oxygen. Its solution at common temperatures is not permanent when exposed to the air, for it undergoes a spontaneous change which may be referred to a decomposing or putrefactive process.

Extract is precipitated from its solution by the acids, and by an aqueous solution of chlorine, in the last case the precipitate being yellow and soluble in hot alcohol. Alkalies and extract combine and form compounds insoluble in water.

Extract combines likewise with the earths, and with the metallic oxides. A combination of the kind is formed when alumina is boiled in a solution of extract, or when an aqueous

solution of its salts is added to that of extract, and the product is insoluble. The same effect takes place with muriate of tin and other metallic salts.

Extract has a strong attraction for the fibres of cotton and linen, and combines with these substances when they are boiled in its solution. The combination is more durable when aided by mordants, which are earthy or metallic compounds that unite to the cloth, and enable the colouring matter to adhere more strongly to its fibres.* The effect is more complete if the cloth be soaked in chlorine, and then dipped into the infusion of extractive. Hence we see that the extractive matter requires no other mordant than oxygen.†

There appears to be almost as many varieties of extract as there are species of plants. The difference of their properties probably, in many cases, depends upon their being combined with small quantities of other vegetable principles, or to their containing different saline, alkaline, acid, or earthy ingredients. Many dyeing substances seem to be of the nature of extractive principle, such as the red colouring matter of madder, and the yellow dye procured from weld.

From the products of its distillation, it seems to be composed principally of hydrogen, oxygen, and carbon, with a little azote.‡

DCCLXXXVI. It has been stated that the extracts commonly employed in medicine differ from that which we have described. They are of a more heterogeneous nature, and consist of all the parts of the vegetable which are soluble in water; such is the case with the extracts of cinchona, catechu, hemlock, opium, belladonna, &c. Rouelle attempted to arrange the different extracts under the three following heads. 1. Mucilaginous extracts. 2. Resinous extracts. 3. Saponaceous extracts. The subject has lately been inves-

* Davy's Agricultural Chemistry, p. 86.

† Thomson's System, 5th ed. vol. iv. p. 63.

‡ Sir H. Davy.

tigated by Braconnot, and by him they have been divided into 5 classes.

1. Azotized extracts—slightly bitter—precipitated by infusion of galls—and yield ammonia by distillation—such as those of borage, bugloss, cochlearia, senna, &c.

2. Azotized extracts—very bitter—contain two animalized principles—yield ammonia by distillation; examples, extract of wild cucumber, marsh tre-foil, nux vomica, &c.

3. Hydro-azotized extracts—very bitter—contain an excess of hydrogen above that necessary to form water with the oxygen present—burn with a bright flame—precipitated by galls; examples, extracts of opium, aloes, colocynth, worm-wood, Carribean bark. poppy, &c.

4. Oxygenized extracts—taste often sweet, sometimes astringent, or acid—contain no azote—are not precipitated by galls—when distilled yield a vegetable acid—usually contain gum; examples, extracts of liquorice, onion, squill, saffron, rhubarb, cassia, tamarinds, rob of elder, currants, &c.

5. Oxygenized extracts—very bitter—not acted upon by galls—yield by distillation much acid, but no ammonia; examples, extracts of gentian, quassia, centaury, &c.*

La Grange and Vogel have considered the extract of saffron as a peculiar principle, and have given to it the name of *polychroite*, but there is no great evidence that it differs essentially from other extractive matter.

SECTION XVI.

Of Gluten.

DCCLXXXVII. Gluten is an important vegetable principle. It exists in the farinaceous grains, but in large proportion only in those of wheat, rye, and barley; it is also found in the juices of some plants, and in the fruits of others, but does not constitute any notable proportion in the esculent roots.

* Annals of Philosophy, vol. xii. p. 34, or Journal de Physique, t. lxxxiv. p. 267.

When wheat flour is made into a paste with cold water, and then washed carefully with successive portions of that liquid, the fecula or starch separates and the substance which remains is gluten. It is a soft solid of a gray colour, of considerable elasticity, and both ductile and tenacious. It is inodorous, but has a faint and peculiar taste. Its structure is fibrous. In this state it possesses a considerable adhesive property, and it is the presence of this substance which gives to flour-paste its power of cementing fragments of porcelain and other bodies.

When moderately heated, its aqueous parts are dissipated, and it is converted into a tough translucent solid, which breaks with a vitreous fracture, and bears a great resemblance to common glue. If exposed to a humid atmosphere, the putrefactive fermentation after a while commences, the mass increases in bulk, produces hydrogen and carbonic acid, and ammoniacal gases, which are evolved, and acetic acid and an oily matter, which remain in the mass; at the same time an odour similar to that which arises from putrefying animal substances is perceived. This kind of action terminates in the production of a substance having the taste and odour of cheese, and filled with holes which contain the same kind of liquid.

When gluten is distilled in close vessels it yields carbonate of ammonia, water, empyreumatic oil, carbonic acid, and carburetted hydrogen gases, hydro-cyanic acid, and charcoal. Hence it is evident that it is composed of carbon, oxygen, hydrogen, and azote, the oxygen probably existing in small proportion compared with the other constituents.

Cold water dissolves but a small portion of gluten; in hot water it loses its elasticity and tenacity. When left long in contact with water, it undergoes a slow decomposition, and is finally converted into carbonic acid, ammonia, a substance resembling *adipocire*, and another analogous to woody fibre.

Gluten is insoluble in alcohol, but Cadet has found that when fermented gluten is triturated with alcohol, and more

of the liquid is added to the mass, a solution is formed which may be used as a very good varnish, and when mixed with lime, as a lute, its adhesive power being strong.*

Sulphuric and nitric acids decompose gluten, but it is dissolved by muriatic and acetic acids. Gluten is likewise soluble in the alkalies, when aided by heat, and it is precipitated from them by acids deprived of its elasticity. Chlorine separates gluten from its combinations; it is likewise precipitated by acetate of lead, and Goulard's extract of lead, by nitrate of mercury, and infusion of galls.

DCCLXXXVIII. Gluten is susceptible of undergoing the species of fermentation which terminates in the production of bread, and in fact that essential article is formed only where gluten is present. Yeast likewise contains gluten.

According to Sir H. Davy, the wheat of warm countries abounds more in gluten and in insoluble parts; it is likewise of greater specific gravity, harder, and more difficult to grind; 100 parts of English wheat furnished him with 19 per cent. of gluten; of Barbary wheat 23 parts; and of Sicilian wheat 21 parts. From the same quantity of barley were obtained 6 parts, and of rye 5 parts of gluten.† Vogel procured from the flour of wheat, the *triticum hyburnum*, 24 parts of gluten, and from the *triticum spelta*, 22 per cent.; 100 parts of rice yielded him 3.60 of vegeto-animal matter.‡

DCCLXXXIX. The physical and chemical properties of gluten, the phenomena it presents when heated, and exposed to the action of various agents, the course of its decomposition, and the products which result, all show a very strict analogy to a substance of animal origin, to which the name of gluten was formerly given, but which is now called *fibrin*. This analogy furnishes a strong argument in favour of the opinion that they are both formed by the same kind of action, and that the powers which operate upon the animal and the

* Tilloch's Magazine, vol. xiii. p. 9.

† Agricultural Chemistry, p. 141—143.

‡ Annals of Philosophy, xii. 38.

vegetable systems are identical, at least so far as organic life is concerned.

SECTION XVII.

Of Albumen.

DCCXC. Some doubts exist whether the substance which has been called vegetable albumen is not merely a modification of gluten, the former existing in the liquid, and the latter in the solid state. Link has shown that there is a very intimate resemblance in properties between gluten and animal albumen, such as is found in the white of an egg.* It has been proved by Vauquelin, on the other hand, that the juice of the *Carica papaya*, a native of the Isle of France, has all the characters of animal matter, and approaches most nearly to albumen. This substance, examined by him in different states, yielded, by exposure to heat, the usual animal products; it was operated upon by different agents in the same way as a solution of albumen, and presented nearly the same appearances when coagulated.

The albumen, which has been examined by other chemists, was obtained from the juices of various plants, such as the cabbage, cresses, scurvy-grass, potatoe, pollen of tulips, &c.

SECTION XVIII.

Of Caoutchouc.

DCCXCI. Caoutchouc, elastic gum, or Indian rubber, is the hardened juice of the *Hevea guianensis*, or caoutchouc, a native of South America. It is also produced, according to Roxburgh, by the *Urceola elastica*, growing in India; indeed the same author has found that several other plants of the same climate yield a juice, which, when concreted, exhib-

* Annals of Philosophy, vol. vii. p. 455.

its nearly the same properties as that of the *Hævea* and *Urseola*.

The first account of this substance was given in 1736, by M. Condamine, one of the French Academicians who visited South America in 1735.

Caoutchouc is brought to us in the form of bottles, and it is prepared by applying the liquid juice over a mould of clay and drying it in smoke; each coating is managed in the same way until a sufficient quantity has been collected. The mould is then broken and its fragments are extracted. Hence the caoutchouc has a colour verging on black. The inspissated juice is naturally yellowish white, and I have seen masses two inches thick of this colour, and filled with holes or eyes like cheese.

As commonly seen, it is a soft, pliable substance, of a deep brown colour, smooth to the feel, of a somewhat fibrous texture, and destitute of taste and odour. Its specific gravity is 0.9335. The property for which it is most remarkable is its elasticity. When extended to many times its usual length it resumes its original size as soon as the extending force is removed. At the moment it is stretched, its temperature, as first noticed by Mr. Gough, rises.

DCCXCII. When heat is applied to caoutchouc it increases in bulk, gives out a disagreeable odour, then melts, and if the heat be sufficiently high, takes fire, burning with a bright light and sending forth much smoke. It will thus burn until entirely consumed. In oxygen gas it burns with great brilliancy. It is remarkable that when once melted it never recovers its former solidity, but continues in a viscid, semi-fluid state. The odour it exhales while consuming is similar to that produced by animal substances. When distilled in close vessels it yields empyreumatic oil, ammonia, charcoal, and some gaseous fluid. Hence azote appears to be an essential constituent, combined with carbon, hydrogen, and oxygen.

Caoutchouc is insoluble in water at any temperature, but when the liquid is hot its edges become soft and very adhesive. It is likewise unaffected by alcohol.

The best solvent of this substance is sulphuric ether which has been previously washed with water ; it takes up a considerable proportion which may be recovered unchanged in its properties by evaporation. Hence this method has been proposed for the purpose of forming flexible tubes for the chemist and surgeon, but it is too expensive to be generally employed. The ethereal solution might probably be used in some cases advantageously as a varnish to coat different articles.

Caoutchouc is likewise soluble in the volatile oils, but when exposed to heat the former is left in a glutinous state.

It is feebly acted upon by the alkalies.

It is completely decomposed by nitric acid, and partially so by sulphuric acid.

DCCXCIII. From what has been stated of its properties it will be seen that few substances of a vegetable nature are less acted upon by various agents than caoutchouc, and this circumstance when taken in connexion with its softness, flexibility, and elasticity, would render this substance very valuable, if means were discovered of manufacturing it with cheapness and facility. At present it is prepared principally for the surgeon by forming it into tubes by a mechanical operation. The best mode, according to Grossart, is to cut it into slips, soften it in hot water, and twist it around pieces of cane or rattan which have been previously split in halves longitudinally and reapplied with a piece of whale-bone interposed between them. The edges of these slips are joined while rendered glutinous by heat, they are made to adhere to each other strongly, and when cold the whale-bone being withdrawn, the pieces of cane will easily follow.

The most familiar use of caoutchouc is to efface pencil-marks from paper, &c. and hence was derived its popular name of *Indian rubber*.

SECTION XIX.

Of Bird-lime.

DCCXCIV. A substance very similar to that of which the properties have just been detailed, is bird-lime. It is formed on the surface of some plants, particularly the *Robinia viscosa*, and gives to its twigs an adhesive property. It may likewise be prepared artificially from the Holly, by boiling the bark in water for 6 or 8 hours, then putting the softened mass into holes in the earth in layers, covering it and allowing it to ferment 2 or 3 weeks, after which, the gelatinous substance is taken out, pounded in mortars, and freed from water.

Bird-lime is a green-coloured, glutinous, and tenacious substance, of a slightly acid taste, and its odour is similar to that of linseed oil. It is fibrous, and possesses so much elasticity that it may be extended to a great length, gradually recovering its former size as the force is removed. By exposure to the air it becomes a dry brown mass which may be reduced to powder.

It is but slightly soluble even in boiling water.

When triturated with strong solution of potash it is converted into a whitish mass, loses its viscosity, and gives out ammonia.

The strong acids decompose bird-lime, while a portion of it is dissolved by those which are weak, and particularly those of vegetable origin.

Bird-lime is likewise soluble in alcohol, ether, and some of the essential oils.

On exposure to heat it goes through changes almost precisely the same as caoutchouc, but leaves a residue of earthy and metallic salts.

SECTION XX.

Of Indigo.

DCCXCV. The indigo of commerce is a lake or pigment obtained from different species of the *Indigofera*, of which the *argentea* yields the best, though not the largest product. It is a very heterogeneous substance, 100 parts containing, according to Bergman, only 47 parts of pure indigo, the remainder consisting of gum, resin, earth, and oxide of iron.

From this mixture indigo may be obtained in its pure state by exposing 15 or 20 grains at a time of this substance of the best quality, and in fine powder, to the heat of a lamp in a glass capsule. At first a bluish vapour of a fœtid odour rises, which is succeeded by one of a purple colour; if the lamp be withdrawn the surface of the mass soon becomes covered with a crystallized substance which may be separated from the scoria beneath by a thin spatula. The product amounts to about $\frac{1}{6}$ part of the indigo employed. Chevreul obtained this substance while distilling indigo, and considered it as the pure colouring matter of that pigment. Brugnatelli gave it the name of *Indigogene*. It is in the form of flattened prisms of a fine purplish red in the aggregate, but of a deep golden yellow when single. Its specific gravity is greater than that of water. On exposure to heat it becomes semi-fluid, at 360° part rises in purple vapour, and may be condensed in very minute crystals, while the remainder is decomposed and leaves a black mass.

It is insoluble in water.

The acids dissolve it with phænomena varying according to the nature of the solvent.

DCCXCVI. When put into concentrated sulphuric acid, it imparts to it a fine green colour, even when the proportion of indigogene is only $\frac{1}{20}$ of a grain to 2 ounces of the liquid. If the proportion of the former be much greater, the solution appears black. When the acid is heated nearly to its boil-

ing point the indigogene is decomposed, and charcoal disengaged. On exposure to the air for a few hours the colour of the solution changes to a deep blue, and this effect is owing to the absorption of water, for the same result is immediately obtained by the addition of $\frac{1}{80}$ of its weight of water. When this sulphuric solution is largely diluted with water, and is allowed to remain at rest for some hours, it is decomposed, indigogene is precipitated of an amethystine colour, and the liquid has a tinge of blue, which may be removed by passing it through filtering paper. This solution of indigogene in concentrated sulphuric acid is decomposed by the alkalies and by lime-water, and a precipitate of a beautiful reddish violet colour is produced.

Indigogene dissolved in nitrous acid by heat, gives it a deep yellowish-red colour, from which potash throws down a precipitate of the same colour, soluble in an excess of alkali.

Its solution in muriatic acid is yellowish green, in alcohol and ether light blue, and in oil of turpentine of a fine green colour. It is likewise soluble in the fixed oils at high temperatures, and as the solution goes on the liquid exhibits a variety of colours; but on cooling the indigogene precipitates unaltered.

Chlorine gas converts it into a yellow mass.

DCCXCVII. Brugnatelli and after him Dobereiner supposed that indigogene, or some part of it, was capable of amalgamating with quicksilver, and therefore ought to be considered as a peculiar vegetable metal.* The experiments which I have made with them do not seem to countenance this opinion.† The effect appeared to me to be owing to the strong adhesion exerted between those bodies. When a mixture of indogogene and perchloride of mercury was exposed to heat, vapours were formed which condensed in minute green coloured prisms, soluble in alcohol, but insoluble in water. From the alcoholic solution nitrate of silver

* Annals of Philosophy, vol. vi. p. 75, and vol. vii. 37.

† New England Journal of Medicine, vol. vi. p. 169.

and ammonia throw down a white, and potash a deep yellow precipitate. The portion undissolved by the alcohol was insoluble in boiling water, and suffered no change in solution of potash, but one portion tinged sulphuric acid deep green, and the other on exposure to heat gave out purple vapours. These green coloured crystals had the properties of a chemical compound.

Indigogene is inflammable, and its flame is dense and red, accompanied with much smoke. When heated in contact with many of the metallic oxides it decomposes them; and it produces the same effect upon the salts which contain a large proportion of oxygen. It explodes with chlorate of potash when the mixture is struck forcibly on an anvil; and the same mixture deflagrates brilliantly when fired in close vessels.

DCCXCVIII. Indigo is deep blue, but exhibits at its surface shades of blue and reddish violet. The lightest is said to be the best. It is insoluble in water and unaffected by the air. By hot water some of the substances contained in it are dissolved, the liquid acquires a yellow colour, and after a while deposits a matter of a green colour, which, on exposure to the air, changes to a blue.

Sulphuric acid is rendered opaque and black by indigo, but when diluted with water it becomes blue. This sulphate of indigo, as it has been called, constitutes what is commonly known by the name of *Liquid blue*, and is employed in the art of dyeing.

DCCXCIX. Nitric acid acts upon indigo with violence, and when highly concentrated and warm even inflames it. When diluted it takes up nearly $\frac{2}{3}$ of the indigo, and forms a deep yellow-coloured solution. During this action oxalic acid and tannin are formed.

DCCC. A substance possessing curious properties and considered by many as a distinct proximate principle of vegetables, is produced during the mutual action of these substances. It is the *amer* or *bitter principle* of Welther, who

obtained it from silk. Haussman first procured it from indigo, and it was shown by Proust, Fourcroy, and Vauquelin, that it might be formed from all organic substances which contain azote.* Chevreul exposed 2 parts of indigo to 4 parts each of nitric acid and water in a retort resting in a sand-bath moderately heated. The action being violent the retort was removed and left in a cold place for 24 hours. The liquid, which was reddish-yellow, contained two substances; one similar to resin, the other of an orange colour disseminated in clots. These solids, after being washed with water, were boiled; they both separated on cooling. The water was then added to the liquid in the retort and distilled. The concentrated distilled liquid on cooling deposited crystals of *amer*, and of a peculiar acid. By solution in water and evaporation the *amer* was obtained in fine yellow scales.

Amer is white with a shade of yellow, volatile, subliming by heat, and condensing in whitish needles or scales, and inflammable. producing, while burning, carbonic, prussic, and nitric acids, nitric oxide, hydrogen, and nitrogen. Hence Chevreul considers *amer* to be composed of nitric acid, and a vegetable matter, probably of an oily or resinous nature.

This principle is soluble in hot water, and the solution is acid and bitter; when mixed with strong solution of potash, it forms crystals in needles and of a golden colour, which explode when heated, and, as observed by Fourcroy and Vauquelin, when wrapped in paper and struck with a hammer. They are soluble in water, but decomposable at a boiling heat in nitric and muriatic acids. *Amer* unites with ammonia, but the compound scarcely detonates. It dissolves several metallic oxides and some of their salts.

DCCCI. Muriatic acid dissolves indigo after it has been precipitated from sulphuric acid by an alkali. The solution is blue. Precipitated indigo is likewise soluble in the fixed alkalies, in ammonia, and in lime-water.

* Chevreul. Nicholson's Journal, vol. xxx. p. 351.

The colour of indigo is permanently discharged by chlorine, and the bleachers judge of the strength of their solutions, by the quantity required to produce this change in the liquid sulphate.

From the results of the distillation of indigo in close vessels, it has been inferred that it consists of azote, carbon, oxygen, and hydrogen, with a little sulphur. It also contains, probably as accidental ingredients, oxide of iron, lime, silex, and barytes.

Indigo, as is well known, is extensively employed to dye cloths of a fine and permanent dark blue colour.

CHAPTER II.

Of the Structure and Chemical Physiology of Vegetables.

DCCCII. The essential parts of a perfect plant are the root, stem, branches, flowers, and seed.

The *stem* may be considered as the middle part of the plant, throwing out ramifications at each extremity, those of the superior part being called the branches, and those at the inferior part the roots. The latter are apparently elongations of the stem or trunk ; they penetrate more or less deeply into the soil, and answer the double purpose of supporting the vegetable, and of furnishing it with nourishment.

The stem or trunk is divided into three parts ; the *pith*, a soft, medullary substance, occupying the centre ; the *wood*, a comparatively hard and fibrous substance, disposed in concentric circles around the pith, and the *bark*, which covers the exterior layer of the wood. In many plants the pith is wanting, and the wood is divided into the *heart-wood*, occupying the centre, and the *alburnum* or sap-wood, surrounding it.

In large plants the part of the bark exposed to the air is rough and laminated ; in smaller plants it is often thin, smooth and shining, and in both it is called the *epidermis* ; immediately below this is the *cellular tissue* or *substance*, composed of fibres, or membranes with interstices between them, filled with a substance of a green colour and soft. This part of the bark is likewise often distinguished by the name of the *parenchyma*. Below this matter are placed the *cortical layers*, which may be considered as the most exterior of the woody circles. In structure they are vascular and constitute an important part of the plant.

The branches are prolongations of the trunk, and they terminate in the leaves, which are composed of two surfaces ; the superior of a smooth and shining appearance, the inferior rough and unequal. These are supported by woody fibres, and enclose vessels of different kinds and destined for different purposes in the œconomy of the vegetable.

The *flower* is composed of the calyx, the corolla, the pistil, and the stamens.

The *seed* varies in form according to the nature of the plant which produces it. Some may be divided into two parts, and these parts are called cotyledons; others are not susceptible of this division. On examining the seed of a bi-cotyledonous plant, such for example as that of the bean, we find that after having separated the coats which enclose it, there appears a small white mass on one side, which is commonly called the *eye*. The seed may then be easily separated into two distinct and equal parts, which constitute the lobes, or cotyledons. The white substance above mentioned then comes more into view, and it is the part known by the name of the *radicle*. It is the rudiment of the future root. Connected with the radicle and presenting a diverging or radiated appearance is another white substance, which is displayed upon the inner surface of the cotyledon, and is called the *plumula*.

DCCCIII. A plant is vascular; the vessels are of different kinds and circulate fluids of different natures, according to their situation and the functions to be performed. One set has its origin in the roots, and these *common vessels*, as they have been called, rise through the alburnum of the stem until they reach the branches, where they terminate in the *central vessels*, which pass through the foot-stalk into the leaf and ramify in all directions. Another set of vessels, called the *proper vessels*, commence in the leaf, converge as they proceed, and finally descend through the alburnum. Accompanying the common vessels is a fourth set, which from their form have derived the name of *spiral vessels*. These are usually empty, and various hypotheses have been proposed to account for their uses.

DCCCIV. When a bean is deposited in the earth under favourable circumstances, it swells and bursts its enveloping membranes, the plumula increases in size, shooting upward, and the radicle elongates downward, constituting the root. A chemical change may be found on examination to have

taken place in the cotyledons. Instead of being insipid and farinaceous, they acquire a sweet and mucilaginous taste, the farina, &c. are more or less completely converted into sugar and form a food adapted to the embryo plant. This process constitutes *germination*, and when it goes on in large quantities of seed, as for example in barley in the process of malting, increase of temperature always accompanies it. The cotyledons are absolutely necessary to the growth of the plant, until the radicle have acquired a certain size, for if they be removed at first, or cut off when they appear above the surface of the soil, the embryo ceases to vegetate. They furnish the only food adapted to the plant in its first stage of existence, but when the root has penetrated into the soil, and has acquired sufficient size and vigour to draw its nourishment from the ground, the office of the cotyledons, which are now considerably above the surface and constitute what are called the seminal leaves, cease, and they wither and die.

Seeds will not germinate indifferently in all situations; hence it appears that there are circumstances which are essential to the commencement and continuation of this process. These circumstances are, 1. A due degree of heat. 2. A sufficient quantity of water. 3. The presence of oxygen gas, or atmospheric air.

DCCCV. But after the food which has been provided in the cotyledons for the embryo plant is exhausted, other conditions are required for its existence. It depends for a part of its nourishment upon the soil, for neither air alone, nor pure water, nor a well regulated temperature, can furnish the materials from which the oak is to be raised from the acorn. Soil is composed of the substances which were formerly ranked among the earths, such as silica, and alumina, with smaller proportions of lime and magnesia, mixed with the remains of animal and vegetable matter, and containing small quantities of the neutral salts, such as nitrates of potash and soda, muriate of soda, carbonates of lime and magnesia, and sulphate of lime. Where plants have vegetated in water

alone, the water has been found to contain carbonic acid, or to hold dissolved substances which were capable of being assimilated.

DCCCVI. Water which has percolated through a soil, appears to dissolve or hold in suspension the substances which are to furnish the vegetable with food, and the liquid is taken into the vessels of the root by absorption. This absorbing power does not apparently act indiscriminately, for like the analogous property in the animal system, those substances which are incapable of contributing to the growth, or might be injurious to the life of the plant, are rejected. The quantity of earthy matter taken into the vegetable system, it is true, is dependent upon the nature of the soil on which it is supported, but the presence of this matter does not impede the healthy actions of the plant, though it does not seem to be essential to its constitution. The liquid thus absorbed constitutes the *sap*; it is found in the common vessels, and in consequence of their action it rises through the roots and stem to the branches, passes into the central vessels and thence through the foot-stalk, into the leaves, where it is circulated through the delicate capillary vessels which are found between their membranaceous coverings. It is here that the changes are effected which convert the crude juices absorbed by the root into a matter capable of supplying the waste or of contributing to the growth of the vegetable system.

DCCCVII. The leaf possesses organs of transpiration, and the superfluous water of the sap is thus evolved. The quantity of aqueous fluid transpired bears in many plants a large proportion to that which has been absorbed. There appears in fact to be an intimate relation between absorption and transpiration, for while plants which grow in a moist soil or climate transpire, others which vegetate in warm climates and in dry soils, lose but little water in this way, and their leaves are full and fleshy. The transpiration takes place from the under surface, for if it be ¹van²ished the passage of the fluid is prevented. The liquid which escapes is water in

its pure state, and it leaves the sap thicker and with a larger proportion of solid nutritive matter.

DCCCVIII. Another function performed by the leaves of plants when exposed to light is the evolution of oxygen gas. The fact appears to be established that vegetables under the influence of the solar rays have the property of decomposing carbonic acid, of appropriating its carbon and disengaging its oxygen. This function exists in the leaves, and it is one of the means by which the growth of plants is promoted. The converse of this however takes place in the dark, and experiments would seem to prove that oxygen is absorbed and carbonic acid evolved. But as all the motions which are going on in a living plant are performed apparently with much less vigour in the night than during the day, it is probable that the oxygen given out in the latter, exceeds the amount of the carbonic acid disengaged in the former period. Hence vegetation has generally been considered as the most effective of the means employed by nature to renovate the atmosphere, and preserve the due proportion of its constituent gases. For immense quantities of oxygen are daily consumed in the processes of combustion, respiration, and the spontaneous decomposition of organic bodies, an equal bulk of carbonic acid, at least in all cases where the oxygen which disappears combines with carbon, is substituted, and if no provision were made for the reproduction of the oxygen, the atmosphere must necessarily be in a state of deterioration. There is no evidence however that the proportion of oxygen in the air is less now than a century ago, and so far as we know, the process of vegetation constitutes the provision by which the uniformity in the constitution of the atmosphere is preserved.

The leaves of plants possess likewise the power of absorbing moisture, and the process takes place when they are secluded from light.

DCCCIX. In fact, light appears to exert a powerful agency upon the processes of vegetation. The beauty and variegated colours of plants apparently result from the opera-

tion of this power or agent, and when deprived of it for some time, the colours grow fainter, and finally disappear, the vegetables become white and are blanched or etiolated. Fruits which grow in the shade, and the parts of melons and cucumbers which rest upon the ground, are destitute of colour. A change to the same extent takes place in their other physical and chemical properties. They lose their taste and odour, the processes of assimilation and nutrition are less perfectly performed, the vessels become loaded with crude insipid juices and the plants, thus deprived of their natural stimulus, lose their healthy vigour and droop. From the phenomena of *etiolation* it may be inferred that the presence of light is necessary to the completion of combinations upon which depend the colour and health of a plant, and that this agent operates partly by its chemical powers to determine such combinations, and in part by its stimulant power upon the irritable fibre of the vegetable. This power of light is not apparently connected with the presence of caloric, with which that principle is usually associated, for experiment seems to have demonstrated that temperature alone, independently of the influence of light, is insufficient to continue the healthy and vigorous exercise of the powers of a plant. The chemical actions which may be referred to the operation of light take place in the leaves, and the first effect of light upon an etiolated vegetable appears upon their edges. The green colour of the vegetable system has been supposed to owe its continuance to solar light. The hypothesis however has been proposed that this green colour is owing to the predominance of an uncombined alkali in the juices of the plant, and that the red colour is the result of the presence of one or more of the vegetable acids.

The functions of the leaves therefore are of the greatest importance to the plant, for it is in them that the actions are to take place which are to terminate in the formation of nutritive matter for the whole system. They seem in fact to exhibit to a certain extent the powers both of the digestive

and respiratory organs of the animal system. These functions are transpiration, or exhalation, absorption of carbonic acid, and evolution of oxygen during the day, and of aqueous fluid, with the disengagement of carbonic acid, during the night.

DCCCX. It has been inferred by some chemists that a portion of the water which is taken into the vegetable system is decomposed, and furnishes to it one or both of its elements. Hydrogen indeed constitutes an essential and often a large part of every vegetable; there must therefore be a constant source from which that element may be derived. This source may be water; it seems probable however that the water is not actually decomposed, but enters into combination with carbon alone, or with carbon and azote, to form ternary or quaternary compounds. The results of M. M. Gay Lussac and Thenard's analyses of several vegetable products rather oppose this conclusion, because in them there was usually an excess of hydrogen over that of the oxygen requisite for the formation of water. The hydrogen contained in vegetables may perhaps be in part derived from the absorption of carburetted hydrogen. Soils contain a greater or less proportion of vegetable matter in a decaying state, and carburetted hydrogen is one of the products of its spontaneous decomposition. If plants possess the power of absorbing and decomposing carbonic acid, that power may be extended to the absorption and appropriation of carburetted hydrogen, and this would be another source both of the hydrogen and carbon, which constitute so large a proportion of the vegetable frame.

DCCCXI. When the sap has thus been circulated through the minute vessels of the leaf, and has undergone the changes in consistence and chemical composition which are essential to its future usefulness, it enters the proper vessels and is transmitted to every part of the vegetable system. This *true sap* or *succus proprius* is of different colours and consistence in different plants. In some it is transparent

and colourless, in some milky, and in others green or red. The vessels which convey it may be traced from the leaf to the alburnum, and it appears to be now generally agreed to by vegetable physiologists, that a portion of the sap is deposited, at a certain period of the plant, in the alburnum, as a reservoir of nutritive matter for the next season. When this is removed, the old alburnum gradually loses its vascular structure and is converted into one of the woody circles. A new alburnum with its appropriate vessels is formed, in which the dense and nutritious sap is again deposited.

DCCCXII. As vegetables derive a part of the materials of which they are composed from the earth, it is obvious that they will flourish best in soils which offer a due proportion of the elementary substances oxygen, hydrogen, and carbon, in a state adapted to their being absorbed by the vessels of the roots. But the earths alone which constitute the bases of soils will not answer this purpose; they require to be mixed with substances of an organic nature in a state of progressive decomposition.

Plants in fact gradually exhaust soils, and this loss of nutritive matter is to be supplied by the addition of *manure*, which is either vegetable or animal matter, or a mixture of both in a decomposed state, or while undergoing decomposition.

The fertilizing substance, known by the name of *mould*, is formed of vegetables alone, and the matter is in a decomposed state.

During the decomposition, carbonic acid and carburetted hydrogen, and if the vegetable matter have contained azote, ammonia, are formed, and a portion of the carbon remains, giving to the mass a dark brown appearance. This decomposition is facilitated by the frequent turning of the mass, so that the whole may be successively exposed to the influence of atmospheric air. The substance which remains is carbon, with the salts which previously existed in the vegetables. By the distillation of 200 grains of mould

Saussure obtained 124 cubic inches of carburetted hydrogen and 34 of carbonic acid, 53 grains of water containing pyrolignite of ammonia, 10 grains of empyreumatic oil, 51 of charcoal, and 8 of ashes. Whence it is evident that the mould contained oxygen, hydrogen, carbon, and azote, the essential elements of organized vegetable matter. When mould is put into water, a portion of it is dissolved, producing a yellowish solution which has the properties of *extractive matter*, and this solution, when applied to the roots of plants, renders them fertile. Animal substances which are used as manures produce by their decomposition the same effects.

All the nutriment of plants, which is derived from the soil, appears to be in solution in water previous to its absorption by their roots; hence when beds of manure are exposed to the air, and are washed by the rain, the liquids which flow from them should be preserved, as they contain a considerable part of the fertilizing substances produced during the decomposition of manure itself.

DCCCXIII. The question now arises, what is the power which causes the circulation of the sap, and the other phenomena of vegetation? Is it mechanical, chemical, or vital? Are the vessels of plants to be considered with Tournefort, as so many capillary tubes into which the various liquids that circulate through the system rise by the attraction between them and the lowest rings of the tubes; or are the motions of the juices to be referred to the operation of gravitation, and the expansive power of heat? The idea that capillary attraction is the immediate cause of these motions cannot now be supported.

There is more plausibility in the second opinion. Sir H. Davy remarks, "the motions of the sap through the bark seem principally to depend upon gravitation. When the watery particles have been considerably dissipated by the transpiring functions of the leaves, and the mucilaginous, inflammable, and astringent constituents increased by the agency of heat, light, and air, the continued impulse upwards

from the alburnum, forces the remaining inspissated fluid into the cortical vessels, which receive no other supply. In these, from its weight its natural tendency must be to descend; and the rapidity of the descent must depend upon the general consumption of the fluids of the bark in the living processes of vegetation; for there is every reason to believe that no fluid passes into the soil through the roots."—This great chemist denies that vegetables possess any power inherent in their fibres analogous to the irritability of animals, and in adverting to the fact stated by Dr. Barton, that camphor promotes the growth of plants by its stimulant operation, he explains it, and perhaps with truth, on the principle of its furnishing elements of nutrition. He regards the opinion of the irritability of plants as improbable for the following reasons. "When a single branch of a vine or any other tree is introduced in winter into a hot-house, the trunk and other branches remaining exposed to the cold atmosphere, the sap will soon begin to move towards the buds in the heated branch; these buds will gradually unfold themselves, and begin to transpire, and at length open their leaves. Now if any peculiar contraction of the sap vessels or cells were necessary for the ascent of the sap in the vessels, it is not possible that the application of heat to a single branch should occasion irritable action to take place in a trunk many feet removed from it, or in roots fixed in the cold soil; but allowing that the energy of the heat raises the fluid merely by diminishing its gravity, increasing the facility of capillary action, and by producing an expansion of the silver grain, the phænomenon is in perfect union with the views hitherto advanced."

Arguments in support of this opinion are likewise drawn from the facts stated by Hales in his *Vegetable Statics*, of the influence of fair and cloudy weather, and of high and low temperature in exalting or diminishing or even suspending the motions of the sap. "Vegetables may be truly said to be living systems, in this sense, that they possess the means

of converting the elements of common matter into organized structures, both by assimilation and reproduction; but we must not suffer ourselves to be deluded by the very extensive signification of the word *life*, to conceive in the life of plants any power similar to that producing the life of animals. In calling forth the vegetable functions, common physical agents alone seem to operate, but in the animal system these agents are made subservient to a higher principle.”*

DCCCXIV. The term life, until lately, has been applied in a vague and indeterminate manner to the effects of the operation of a single principle, which has been supposed to reside in one set of organs.

It may be seen however that all organic beings possess certain properties in common, while they differ essentially from common matter. In comparing animals and vegetables a strict conformity will be observed in those properties which are to form and preserve the species. In both of these results are obtained by the processes of circulation, assimilation, nutrition, and reproduction; and in both can be seen those of transpiration or exhalation, secretion, excretion, and absorption. But in the one these functions alone make their appearance, while in the other they are associated with the senses, which connect the animal system with the external world, with the powers of loco-motion, and with the voice. All these various functions are the result of life, but in different degrees, and hence they admit of the classification made by Bichât, into Organic, and Animal life. Now in the animal the functions of organic life or the motions on which these functions depend, are regulated by the irritability of the fibre, and we have a right to infer that in whatever systems the same functions are found to be performed, the same property of irritability exists. As vegetables are vascular, and circulate fluids, as these fluids undergo modifications which adapt them to the wants of the system, as a portion

* Davy's Agricultural Chemistry, pp. 244—250.

of them is converted into nutritive matter and appropriated, while the remainder is thrown out by transpiration or secretion, it seems reasonable that these motions should be produced by the same cause in them as in animals. Sir H. Davy objects to the idea that camphor operates upon the roots of vegetables as a stimulant. A fairer example may be found in gypsum, plaster of Paris, the sulphate of lime of chemist. This substance, it is well known, increases the fertility of soils, yet it furnishes nothing which is nutritive; it has in its usual state little or no attraction for water, and it operates in no obvious way to facilitate the decomposition of those substances which are capable of affording nutritive matter to plants. What then is its mode of operation? It was inferred by Sir H. Davy that its use was to combine with the fibre of grasses and constitute an essential part of their substance. This is by no means a satisfactory solution of the question, for the increase of weight in a crop of wheat or of indian corn, arising from the use of gypsum, must greatly exceed the weight of that substance employed. It seems most reasonable therefore to infer, that it operates by its stimulant power, by which the roots of plants are elongated and rendered more vigorous, and consequently capable in a given time of absorbing more nourishment from the soil. Many of the neutral salts probably act in the same way. Arguments in favour of this opinion have likewise been drawn from the effects of heat and light upon vegetables, and from the spontaneous motions which take place in some of them when acted upon by foreign bodies. It has even been maintained that plants are possessed of sensibility; but the opinion will appear improbable when it is recollected, that no direct proof of the fact has yet been discovered, that no organ adapted to the purpose is known to exist, and that it is hardly to be supposed that a being susceptible of pain should have been left so defenceless and yet exposed to such innumerable sources of violence and death.

CHAPTER III.

Of the spontaneous decomposition of vegetables.

DCCCXV. During the life of plants, actions are continually going on, which may be referred partly to the chemical, and in part to the vital powers of the system, the former being apparently subordinate to the latter. But so soon as vitality ceases, another series of changes commences, which results in the decomposition of the vegetable. Its elements unite in a manner essentially differing from that which takes place while alive, disorganization gradually ensues, and the plant finally falls down into soil or mould. The changes which thus terminate in the destruction of organic substances have been classed under the general head of Fermentation ; and this has been subdivided into the Vinous, which produces an intoxicating liquid, the Acetous, which ends in the formation of vinegar, and the Putrefactive, which reduces it to mould. To these has been added a fourth, viz. the Panary, the product of which is bread ; but, as observed by M. Thenard, this is rather to be considered as a mixture of the vinous and acetous, and may therefore be detailed after the phænomena of the last have been described.

1. *Vinous Fermentation.*

DCCCXVI. Of the proximate principles of plants, sugar is the one which is usually made to undergo the changes that constitute the vinous fermentation ; but in order to excite and continue it, certain conditions are necessary. These are the presence of water, a certain range of temperature, and the addition of some substance which has the power of commencing the action. For it is well known, that syrup alone, although its constituents, sugar and water, may be in just proportion, and aided by a sufficient degree of heat, is incapable of change. The substance thus required is yeast or ferment, which is usually obtained from beer, and is then used in the

form of a dark brown, viscid liquid. In some countries it is prepared in a solid form, in which state it still retains its power of producing the fermentative process, when mixed with the requisite materials. All the juices of fruits which are capable of going through these changes independent of addition, such as those of grapes, apples, and pears, contain ferment. In Paris, ferment obtained from beer is sold in the state of a grayish white paste, firm and brittle, which loses two thirds of its weight on drying, and which when enclosed in a vessel and exposed to a temperature from 60° to 80° Fah. undergoes in a few days the putrefactive fermentation. On exposure to a warm atmosphere it absorbs oxygen and produces carbonic acid and water. It is insoluble in water and alcohol, and if put into boiling water, it afterwards loses its power of creating fermentation in a solution of sugar for some time. Ferment is analogous in composition to vegetable gluten, or at least besides the usual elements of vegetables it contains azote.*

DCCCXVII. Now if about 5 parts by weight of sugar be dissolved in 20 of water, if the solution be exposed to a temperature between 55° and 75° Fah. and a small quantity of yeast or ferment be added, an intestine motion will soon be observed in the liquid, bubbles of gas will rise to the surface, together with a portion of the yeast and form a scum or froth, the liquid will grow turbid and increase both in bulk and in temperature, and during the whole process will discharge an elastic fluid. These motions will continue a longer or shorter time according to the quantity employed, and the degree of heat to which the materials have been exposed; they will then gradually cease, a sediment will subside and the fluid, now become comparatively clear, will have a pleasant taste and odour, and possess the power of intoxicating. This series of changes and this kind of product constitute the vinous fermentation. The decompositions and combinations which occasion it are obviously of the most complicated

* Thenard. *Traité de Chimie*, t. iii. p. 341, 2 edit.

kind, and they have been made the subjects of much research and experiment. It appears, 1. That when solution of sugar is fermented by means of yeast, the presence of atmospheric air is not necessary to the process. 2. That the whole of the sugar suffers decomposition. 3. That the ferment is decomposed, but only in small quantity, 100 parts of sugar requiring only $1\frac{1}{2}$ part of this substance independently of its water. 4. That carbonic acid is disengaged; and, 5. That alcohol is produced and remains in the liquid. Hence the conclusion has been drawn, that the principal change in vinous fermentation is in the composition of the sugar, and the following rationale of the process has been given by M. Gay-Lussac. Sugar is composed in round numbers of 40 parts of carbon and 60 of oxygen and hydrogen, which he infers are united in the form of water. According to the theory of volumes it consists of

1 volume of the vapour of carbon,

1 volume of the vapour of water;

or of

3 volumes vapour of carbon,

3 volumes of hydrogen,

$\frac{3}{2}$ volumes of oxygen.

Alcohol is composed of

1 volume olefiant gas = $\begin{cases} 2 \text{ volume vapour of carbon,} \\ 2 \text{ volumes of hydrogen.} \end{cases}$

1 vol. vapour of water = $\begin{cases} 1 \text{ volume hydrogen,} \\ \frac{1}{2} \text{ volume of oxygen.} \end{cases}$

Now in order to convert sugar into alcohol it is only necessary to abstract 1 volume of carbon and 1 volume of oxygen. These by their union will constitute the volume of carbonic acid evolved, while the remaining elements combine and form alcohol. When these are reduced to weight, 100 parts of sugar will be found to yield by the vinous fermentation 51.54 parts of alcohol, and 48.66 of carbonic acid.*

* Annales de Chimie, t. xciv. p. 316. Thenard. Traité de Chimie, iii. p. 416.

The result of vinous fermentation is a liquid which has an intoxicating quality, but the appearance and taste of which depend upon the vegetable substance fermented. They may be reduced to two kinds; wine, which is the product of the juice of the grape, and beer, which results from changes that have taken place in the farinaceous grains.

Wine.

DCCCXVIII. The juice of the grape contains, according to Thenard, a large proportion of water, considerable sugar, a peculiar substance very soluble in water, and a small quantity of mucilage, of nitrate of potash, tartrate of lime, common salt, and sulphate of potash. It is incapable of fermenting out of contact with the air. When expressed from the grape, it undergoes an active fermentation, and is subsequently drawn off from the sediment; it then proceeds through a second fermentation, which is much less energetic but is of longer duration than the first, and gradually deposits a quantity of colouring matter mixed with tartar forming the lees.

White wine is obtained from the juice of the white grape, or from the black grape when deprived of its skin. If the cuticle of the coloured grape be fermented with the juice, the wine is red. Wines vary in strength and flavour according to the quality of the grape, the climate, and the more or less perfect fermentation to which they have been exposed. If they be bottled before the second fermentation is over, a quantity of carbonic acid is generated, which gives to them a sparkling quality, and a brisk, lively taste. Such are the wines of Champagne. Some are sweet, the fermentative process having been checked before completed; some have an astringent taste, owing probably to the presence of tannin, while others are spirituous. Every species of wine possesses a peculiar flavour and odour, which has been supposed to depend upon the presence of an essential oil, which has not yet been obtained in a separate state.

DCCCXIX. The quantity of intoxicating liquid, or, in other words, the amount of the alcohol contained in the different fermented liquors, varies considerably in different species, and with regard to wines likewise according to their age. Old Madeira, it is said, is stronger than that which is new, and it may be owing to the gradual conversion of the materials, at least all those which are susceptible of it, into alcohol, by the slow fermentation to which we have before alluded. A series of interesting experiments has been made by Mr. Brande upon the strength of various vinous liquids, and the relative quantity of alcohol in several of them was as follows.

Lissa	-	-	-	-	-	-	25.41 per. cent.
Raisin wine	-	-	-	-	-	-	25.12
Marsala	-	-	-	-	-	-	25.09
Port	-	-	-	-	-	-	22.96
Madeira	-	-	-	-	-	-	22.27
Sercial	-	-	-	-	-	-	21.40
Sherry	-	-	-	-	-	-	19.17
Teneriffe	-	-	-	-	-	-	19.79
Lisbon	-	-	-	-	-	-	18.94
Malaga	-	-	-	-	-	-	18.94
Cape Muschat	-	-	-	-	-	-	18.25
Cape Madeira	-	-	-	-	-	-	20.51
Calcavella	-	-	-	-	-	-	19.20
Vidonia	-	-	-	-	-	-	19.25
Claret	-	-	-	-	-	-	15.10
Sauterne	-	-	-	-	-	-	14.22
Burgundy	-	-	-	-	-	-	14.57
Hock	-	-	-	-	-	-	12.08
Champagne	-	-	-	-	-	-	12.61
Red Hermitage	-	-	-	-	-	-	12.32
Vin de Grave	-	-	-	-	-	-	13.20
Frontignac	-	-	-	-	-	-	12.79
Cider	-	-	-	-	-	-	50

Perry	-	-	-	-	-	7.26 per. cent.
Ale (Burton)	-	-	-	-	-	8.88
London Porter (average)	-	-	-	-	-	4.20
Small beer (ditto)	-	-	-	-	-	1.23

Distilled liquids.

Brandy	-	-	-	-	-	53.39
Rum	-	-	-	-	-	53.68
Gin	-	-	-	-	-	51.60
Scotch Whiskey	-	-	-	-	-	54.32
Irish ditto	-	-	-	-	-	53.90

Beer.

DCCCXX. Grains of barley, after having been steeped in cold water for at least 40 hours, by which they are made to increase both in bulk and weight, from the absorption of water, are drained, and formed into a mass about 16 inches deep. In this state it absorbs oxygen, disengages carbonic acid and increases in temperature, which is regulated by turning the mass and exposing the different portions successively to the air. In this situation germination takes place, both the radicle and plumula increase in size, and the substance of the cotyledons is in part converted into saccharine matter. The period at which it is necessary to put an end to this process is determined by the length of the little root which has thus been brought out by the living powers of the seed, and this is effected by drying it in a kiln. The barley has then undergone the operation of malting and the mass is known by the name of *malt*. This is infused in water of the temperature of from 160° to 180°, after having been ground in a mill, and the liquid constitutes *wort*. It is a liquid of a brown amber colour, of a peculiar odour, and sweet cloying taste, which is subsequently boiled with hops, which gives to it sapidity, and a disposition to resist longer the tendency to run into the acetous fermentation, and the whole is poured

into vats where it is mixed with yeast and allowed to ferment. The product of this process is ale, porter, or beer, according to the quantity of water and of saccharine matter, and the duration of the processes of malting and fermenting. From the chemical changes which take place during malting, it is obvious that the cotyledons suffer the same modifications in composition as in ordinary germination. The fecula appears to be converted into a matter which is very similar in properties to sugar, and the intoxicating property, which the different species of beer are known to possess, is owing to the subsequent decomposition of this saccharine substance by chemical causes the same as those already detailed, and its conversion into alcohol and carbonic acid. But as it exists in much smaller proportion in wort than in the juice of the grape, the liquid produced from it is comparatively weak and more disposed to become sour.

Beer may be formed from every species of corn.

Alcohol.

DCCCXXI. When any liquid which has undergone the vinous fermentation is distilled, the liquid obtained, provided the process have been stopped when one half has come over, has a stronger taste and acts much more powerfully as a stimulant upon the animal system. The distilled liquids are known in commerce by different names, according to the substances from which they are procured. When the different species of wines are distilled, the product is *brandy*; the fermented juice of the sugar-cane, and its uncrystallizable part called molasses, yield *rum*, and the farinaceous grains, whiskey and gin. Even in these however the pure spirituous part, as may be seen in Mr. Brande's table, is diluted with nearly an equal bulk of water. Hence when it is required in a more concentrated state, other processes must be resorted to, for the purpose of separating the water. If brandy be distilled at a moderate heat until one half is condensed in the

receiver, a rectified spirit is obtained, which may be rendered still stronger by a second or third distillation; but as it still contains water, the method practised by chemists to free it from this liquid is to add to it some of the salts which have a strong attraction for water, such as carbonate of potash or muriate of lime. In order to obtain a small quantity, a portion of *spirit of wine* may be distilled in a retort connected with a large receiver kept cool, until two thirds or three quarters have come over; this is to be put into a retort connected as above, to it is to be added dry and warm pearl-ash in the proportion of 1 ounce of the former to 1 pint of the latter, and redistilled. The salt attracts the water and forms a dense solution which remains in the retort. To destroy the slight flavour communicated to the spirit by the salt, the liquid may be again distilled with the addition of alum in the quantity of $\frac{1}{8}$ of an ounce; the excess of acid in this salt will combine with and remove the small quantity of carbonate of potash previously dissolved. When the spirit thus procured is distilled slowly and cautiously one or more times from muriate of lime or pure potash, it is then obtained in a state of purity, and is known by the name of *alcohol*. By these processes it is precisely the same from whatever fermented liquor it may have been distilled.

DCCCXXII. It is a transparent and colourless liquid, of an agreeable odour, but hot and pungent taste. It operates powerfully upon the system, producing in the first place high excitement and intoxication, followed by a proportional debility in the organs of the body. In large quantities it induces insensibility, convulsions, and death. The specific gravity of alcohol varies according to the processes employed in separating it. The standard specific gravity is 0.825, but it was obtained by Dr. Black as low as 0.800, and by Lowitz at 0.791. Alcohol is volatile and on exposure to the air passes into vapour with more rapidity than water, and produces a greater reduction of temperature. It boils under the medium pressure of the air at 165° , and in the vacuum of an air-pump

145° lower. The specific gravity of its vapour, air being unity, is 1.613. Pure alcohol has never been obtained in a solid state, at least no process for congealing it is yet generally known, though Mr. Hutton of Edinburgh affirms that he succeeded in converting it into ice at a temperature below — 110° Fah. His method however is still a secret. It is in consequence of this property that alcohol is employed as a thermometric liquid to measure intense degrees of cold, and it has an advantage over mercury in this respect that below zero its contractions are more regular and more corresponding with the decrements of heat.

DCCCXXIII. Alcohol mixes with water in all proportions, and the mixed liquids increase in temperature and diminish in volume, so that the specific gravity of the mixture is greater than that of the mean of the two liquids. This kind of chemical union, if it may be called such, is precisely analogous to that of water with sulphuric acid. When mixed in equal volumes, the specific gravity of the alcohol being 0.817, and that of the water 1.000, the density is increased to 0.934. As this difference diminishes with the excess of the water over the alcohol, the strength of the spirit, or in other words its specific gravity, can be found only by the hydrometer, or gravimeter, of which Nicholson's is perhaps the most convenient. As it is of consequence in commerce to ascertain the strength of distilled spirits, tables have been constructed for the purpose of showing the quantity of pure alcohol contained in liquids of different specific gravities; of these the tables of Mr. Gilpin, which may be found in the Philosophical Transactions for 1794, are the most extensive. The diminution in bulk on mixing alcohol and water may be measured on a small scale in a simple and convenient apparatus invented by Mr. Brande.*

DCCCXXIV. Alcohol, in consequence of its disposition to combine with water, is capable of precipitating some of the

* Manual of Chemistry, p. 405.

neutral salts and several of the proximate principles of vegetable and animal bodies from their aqueous solutions. But it dissolves the deliquescent salts, which tinge its flame of various colours, all the resins, and the caustic alkalies, leaving their carbonates. It likewise dissolves a small proportion of phosphorus and sulphur, but has no effect on charcoal or carbon. Resinous solutions are called *tinctures*.

DCCCXXV. Alcohol is highly inflammable, and when a flame is applied it takes fire, burning with a light lambent flame, and producing carbonic acid and aqueous vapour. Hence it may be used in a lamp with a common wick, and in many experiments it will be found much more convenient than oil, as it affords no smoke which can soil the apparatus above. When used in this way, with a coil of fine platina wire partly upon and partly above the wick, it produces the *lump without flame*, in which the alcohol suffers such changes as to give out sufficient caloric to preserve the metal at the temperature of ignition while the hot metal in its turn keeps up the action upon the vapour of the alcohol. The result is the *Lampic acid* of Mr. Daniell.

Lavoisier was the first who endeavoured, by collecting the products of its active combustion, to ascertain the nature and proportion of its elements. The subject was afterwards more accurately examined by Saussure jun. and Gay-Lussac, and the conclusion has been drawn that alcohol is composed of oxygen, hydrogen, and carbon in the proportions to form one volume of olefiant gas, and 1 volume of the vapour of water; by weight of 61.63 of the former, and 38.37 of the latter; in considering it as a ternary compound rather than a binary, it will consist of about 13.70 of hydrogen, 51.98 of carbon, and 34.32 of oxygen.

Ethers.

DCCCXXVI. When alcohol is mixed with some of the acids and the mixtures are distilled, peculiar volatile liquids

pass over which are called ethers, and which in their general characters are analogous to alcohol. Their specific names are derived from the acid from which they are produced, such as sulphuric, nitric ethers, &c.

DCCCXXVII. 1. *Sulphuric ether*. To form this ethereal liquid, a quantity of alcohol is put into a deep-bodied thin retort, and through the tubulure an equal weight of strong sulphuric acid is poured. The mixture grows brown, exhales a fragrant odour, and increases in temperature. The beak of the retort is then to be connected with a large receiver immersed in ice or cold water, heat is applied to the body which contains the materials, ebullition takes place, and a quantity of vapour is formed, which condenses in the neck and flows down its sides in striæ. The distillation is to be suspended, when thick white fumes rise from the liquid, which happens when the fluid obtained amounts to about half the bulk of the alcohol employed. By the addition of a new quantity of alcohol to the acid in the retort, another product of ether may be obtained, and repeated distillations from the same acid may thus be effected. Ether procured in this way contains alcohol, water, and sulphurous acid, from which it may be freed by *rectification*, which consists in distilling it from a small proportion of pure potash, in the proportion of 2 drachms to 1 pound, by a gentle heat. Lime will likewise answer the purpose; and black oxide of manganese has been employed, which converts the sulphurous into sulphuric acid. The ether still contains a small quantity of alcohol, which may be removed by washing it with pure water.

Towards the conclusion of the process for preparing this liquid, two other compounds are formed, olefiant gas and sweet oil of wine.

DCCCXXVIII. Sulphuric ether is a colourless and transparent liquid of a peculiar, fragrant odour, and hot pungent taste. Its specific gravity is 0.716. It is highly volatile; on exposure to the air it speedily evaporates, and a drop of it is dissipated before it passes through 4 or 5 feet of air. Its

odour is soon diffused through a large apartment. If a little ether be poured into the hand or upon any part of the body exposed to the air, a very distinct sensation of cold will be perceived. The reduction of temperature during its spontaneous evaporation is such that water may be easily frozen, even in the summer season, by putting it into a small and thin glass tube, surrounding it with muslin or sheet lint, dipping it into ether, and then agitating it in the air. An attenuated stream of this liquid, directed upon the bulb of a small thermometer through a syringe with a fine bore, will sink its temperature many degrees below zero. In the vacuum of an air-pump it boils actively and produces a degree of cold which, if Mr. Robison's observation be correct, is equal to -47° , or 145° below its boiling point under medium pressure. Hence it is easy to congeal water and several other liquids during its vaporisation. When ether is exposed to heat it boils at the temperature of 98° , and the specific gravity of its vapour, air being unity, is 2.5860.* From the tendency of this liquid to assume the elastic form, it appears that when added to any air it doubles its volume. Ether congeals at the temperature of -47° , or -48° .

DCCCXXIX. Ether is more inflammable than alcohol, and when fired it burns with a flame which is whiter and denser, and if pure is entirely consumed; the products are carbonic acid and water; a thin film of charcoal is generally left adhering to the sides of the vessel. The vapour of this liquid is equally inflammable, and it has not unfrequently happened that so much of this vapour has been accumulated in laboratories in which it was prepared, that it has suddenly taken fire from the flame of a lamp or candle, and produced serious consequences. This source of danger might be entirely obviated by lighting the room with one or more of Sir. H. Davy's safety-lamps.

DCCCXXX. When ether is introduced into a vessel containing oxygen gas, the volume of the air is doubled; if a

* Gay-Lussac.

flame be applied, it takes fire, and burns with great brilliancy, but without explosion; but if 1 part of this etherised oxygen be added to 3 parts of oxygen, and fired, a violent detonation ensues. It is said likewise to be inflamed by chlorine.

✓Ether is dissolved in small proportion by water, but is soluble in all proportions in alcohol. It takes up a small quantity of sulphur and phosphorus, and some of the vegetable principles, particularly camphor, resin, and essential oil. It is the best solvent of caoutchouc.

Ether is employed in medicine as a stimulant, and it is used in the art of gilding.

DCCCXXI. The composition of ether has been determined by the results of its combustion, and by those of its decomposition when transmitted over the surfaces of an ignited tube. It appears that while burning, 1 part of ether absorbs 3 parts of oxygen, and produces $1\frac{3}{4}$ parts of water, and $2\frac{1}{4}$ of carbonic acid. According to Saussure it is composed of

Hydrogen	-	-	-	-	-	14.40
Carbon	-	-	-	-	-	67.98
Oxygen	-	-	-	-	-	17.62
						<hr/>
						100.00

and that it may be represented by the elements of 100 parts by weight of olefiant gas, and 25 of water. Hence M. Gay-Lussac considers it as a compound of

Olefiant gas	-	-	-	-	2 volumes
Vapour of water	-	-	-	-	1 volume

condensed into 1 volume.

This view of its constitution will assist us in forming some idea of the operation of sulphuric acid in the production of this liquid. Alcohol is composed of 1 volume each of olefiant gas and of the vapour of water or its elements in that ratio, and the effect of the acid appears to be to abstract one half of

the water, or to cause the oxygen and hydrogen to unite in such proportions as to form it, and by that means to convert the remainder from alcohol into ether.

DCCCXXXII. 2. Nitric ether. When nitric acid is added to an equal weight of alcohol, bubbles which are at first small begin to rise, they soon become of greater magnitude and in larger quantity, the temperature increases, a violent effervescence takes place, and nitric ether, which towards the conclusion is mixed with nitric oxide gas, is rapidly produced. The action is so violent, that it is dangerous to operate upon large quantities. Hence various processes have been proposed to obtain nitric ether with safety. Artists, it is said by Dr. Thomson, make use of Chaptal's method, as improved by Proust,* but Dr. Black's may be employed with ease. It consists in putting the alcohol into a proper vessel, pouring slowly through a funnel which shall reach to the bottom, a small quantity of water, and then adding the due proportion of acid. Thus there will be three distinct strata, which after a while will mingle, and by their mutual action produce nitric ether, which may afterwards be obtained by distillation.

DCCCXXXIII. Nitric ether is a liquid of a yellowish colour, transparent, and of a peculiar and fragrant odour. It usually contains a small portion of nitrous acid. When freed from this acid, it has a hot and pungent taste, its specific gravity is intermediate between that of alcohol and water, and it is so volatile that it boils at the temperature of 70° Fah. Hence it enters into ebullition when poured into the hand, and at the same time produces the sensation of cold. It is highly inflammable, takes fire readily and burns entirely away. When agitated with 25 or 30 times its weight of water, it divides into three portions; one, which is small, is dissolved, one is vaporised, and the third is decomposed. The aqueous solution becomes at once acid, which when satur-

* Thomson's Chemistry, vol. ii. p. 338; or Annales de Chimie, t. xliii. p. 262.

ated with potash and submitted to distillation, yields alcohol and nitrate of potash. It likewise becomes acid when allowed to remain at rest for a few days in a close vessel. It resists for some time the action of a solution of potash. Forty one parts and a half of nitric ether, passed through a red hot tube, yielded 5.63 parts of water, containing a little prussic acid, 0.40 of ammonia, 0.60 of oil, 0.50 of carbon, 0.75 of carbonic acid, 29.90 of elastic fluid, consisting of nitric oxide, azote, carburetted hydrogen, and carbonic acid, 3.72 loss.*

Nitric ether increases the bulk of a gas no less than 5 times its original volume.

This liquid was considered by Thenard as a quaternary compound of oxygen, hydrogen, azote, and carbon; but the actions which produce it are exceedingly complicated, both liquids are decomposed, and numerous products are obtained, which are probably varied by the degree of strength of the materials, and circumstances attending the experiment.

A liquid, which is employed in medicine by the name of dulcified, or sweet spirits of nitre, is formed by adding nitric acid to an equal weight of proof spirit, allowing them to remain in contact in a cool place for two or three days, and then distilling the mixture. The portion which passes over is nitric ether mixed with alcohol.

DCCCXXXIV. 3. *Muriatic ether.* This compound is formed with considerable difficulty; hence various processes have been employed, of which that of M. Thenard is perhaps the best.†

In its purest form muriatic ether above the temperature of 52° Fah. is gaseous, transparent, and colourless, and incapable of changing vegetable blues to a red. It has a sweet taste, and a strong smell, and its specific gravity, air being unity, is 2.219. Below 52° it is condensed into a liquid, the specific gravity of which at 41°, compared with that of water,

* Thenard. *Traité de Chimie*, t. iii. p. 287; or *Mem. D'Arceuil*, t. i. p. 75.

† *Traité de Chimie*, t. iii. p. 283; or *Nicholson's Journal*, vol. xviii.

is as 874 to 1.000. When poured upon the hand, it boils, evaporates, and leaves the sensation of considerable cold. Exposed to a dull red heat in passing through a tube, it is decomposed, and resolved into muriatic acid, and olefiant gases. In a very high heat it yields light carburetted hydrogen gas and deposits a considerable portion of carbon. It is highly inflammable, burns with a green flame, and forms muriatic acid and carbonic acid gases, and aqueous vapour. The same results are obtained by burning it in contact with oxygen gas. If the volume of the oxygen is to that of the ether as 3 to 1, the mixture produces, when ignited by a flame or by the electric spark, a violent explosion.

Water absorbs its own bulk of gaseous ether at the temperature of about 62°; the solution has a taste which is sweetish and similar to that of mint. Although very soluble in alcohol, it may be separated from that liquid by water. The acids when hot decompose it, and the same effect is produced more slowly by the alkalies, which require to be in contact with it several days.

From the experiments of M. Thenard, and of M. M. Colin and Robiquet, muriatic ether may be considered as a compound of 1 volume of muriatic acid gas, and 1 volume of olefiant gas condensed into 1 volume. Thenard describes this liquid by the name of *hydro-chloric ether*.

DCCCXXXV. 4. Alcohol is likewise capable of furnishing ethereal fluids with hydriodic, phosphoric, arsenic, and acetic acids. The vegetable acids, such as the benzoic, citric, oxalic, &c. may by peculiar management be made to form with alcohol liquids analogous to the ethers already described.

Acetous Fermentation.

DCCCXXXVI. When liquids, such as beer, cider, and the weak bodied wines, are exposed to the air and to a temperature above 65°, a series of actions ensues which terminates in the production of vinegar. To this kind of fermentation is applied the name of acetous. The liquid grows turbid,

the different parts are observed to be in motion, and as the process advances, the taste and odour of the substance are changed. This action continues for a certain time, longer or shorter, according to the circumstances of the experiment; it then ceases, and the liquid by depositing a portion of insoluble substance becomes clear.

The circumstances necessary to the acetous fermentation are, 1. the contact with oxygen gas, 2. the presence of alcohol, saccharine matter, fecula, or vegetable gluten.

Alcohol alone or diluted with water is incapable of undergoing this change, but those substances which are susceptible of the vinous fermentation may likewise, when the temperature is increased, go through the acetous and be converted into vinegar. Even strong and generous wines will not experience this change. But if to wine or diluted alcohol a quantity of vegetable substance which contains gluten or fecula be added, such as yeast, the juice, or husks of the grape, &c. then the actions commence which terminate in the production of vinegar. In proportion as the liquid becomes sour, it loses its spirituous taste and its power of intoxicating, and when completed, the alcohol can no longer be detected. Whence it appears that as the conversion of sugar into alcohol constitutes the vinous, so the change of alcohol into the acid of vinegar characterizes the acetous fermentation.

DCCCXXXVII. It has been found a difficult problem to solve the nature of this change. It would appear by the researches of Th. Saussure, of Thenard, Cadet, and others, that the oxygen required in this process is not absorbed and made to combine with the elements of the alcohol, but is expended in uniting with a part of its carbon which passes off in the form of carbonic acid. For it was found by Saussure that the volume of acid gas disengaged was precisely equal to that of the oxygen which had disappeared. Hence the conclusion might be drawn that the acid thus produced differs from alcohol only in containing a smaller proportion of carbon,

The facts just stated refer to the formation of vinegar from wine and diluted alcohol. There are other cases however in which this change takes place independently of the air; thus when sugar is dissolved in water in which the gluten of wheat has fermented, the solution will become sour even in close vessels; and the same effect will be produced in wort, which does not contain the bitter principle of hops. Cider and beer likewise finally undergo the acetous fermentation, although they may be excluded from the air.

DCCCXXXVIII. The liquid into which vinous substances are changed by this process is *vinegar*. According to Cadet a good vinegar may be formed by making a solution of 124 parts of sugar in 868 of water, adding to it 80 of yeast, allowing it to ferment a month and then straining the liquid. Vinegar is generally of a light reddish yellow colour, of a sour taste, agreeable and pungent odour, and of a specific gravity varying from 1.0135 to 1.0251. It may be rendered colourless without losing its flavour by being filtrated through dry charcoal powder. It contains some of the other vegetable acids, such as the malic and tartaric, as also gluten, mucilage, and extractive or colouring matter. In this state it is liable to a spontaneous decomposition, which, according to Scheele, may be prevented by boiling it for a few minutes and separating the insoluble parts. When subjected to distillation until $\frac{2}{3}$ have passed over, of which the last portions are much the strongest, it is obtained in a more concentrated state and is known in commerce by the name of *distilled vinegar*; in chemistry it was formerly called *acetous acid*.

In the distillation of wood, an acid liquid is obtained in considerable proportion, and has been known as the *pyroligneous acid*. It contains vinegar disguised by the presence of empyreumatic oil, from which it is freed by distillation in contact with animal charcoal.

In France it is procured in a pure and strong state by saturating it with chalk, removing the impurities, boiling the liquid and then decomposing the acetate of lime thus form-

ed by sulphate of soda. By these means acetate of soda and sulphate of lime are produced, the former remaining in solution, while the latter is precipitated. The acetate of soda when obtained pure by frequent solutions and crystallizations, is dissolved in water in small proportion, an equal weight of sulphuric acid is added, sulphate of soda crystallizes, and the acetic acid thus procured is still further purified by distillation. Vinegar may likewise be concentrated by allowing it in part to freeze, and distilling the remainder; if this likewise be subjected to the same process, a strong acid will be the result.

DCCCXXXIX. Now the acid which gives the sour taste and pungency to all vinegars is the *acetic*; but as even in the strongest of these it is considerably diluted with water, chemists procure it free from this liquid by an indirect method, which consists in the decomposition of some of the salts of which it constitutes one of the ingredients. The acetates commonly employed are those of potash and soda, or of some of the metals, viz. of copper and lead.

When *verdigris* is distilled at a strong heat in a retort of earthen ware coated, thick vapours arise which may be condensed in a receiver kept cold by ice or water. It is usually coloured green from the presence of acetate of copper and requires a second distillation. From 16 ounces of this salt may be obtained about 4 ounces of concentrated acetic acid, which received from the earlier chemists the names of *Radical vinegar*, and *vinegar of Venus*. Another method consists in decomposing acetate of potash or soda by sulphuric acid alone in the first case, or bi-sulphate of potash in the second, and distilling off the acetic acid.

For some years it was supposed that there existed two acids, the acetous and the acetic, which differed from each other in their degrees of oxygenation. But later researches have proved this opinion to have been erroneous. There is but one acid, and one set of salts to which it gives generic characters.

Acetic Acid.

DCCCLX. Acetic acid at the temperature of 60° Fah. is a transparent and colourless liquid, of a very sour and sharp taste, and of a pungent odour. It is so caustic as to excoriate the skin. Its specific gravity is 1.063. When reduced to 55.5°, it congeals and appears in the form of foliated arborescent crystals. When added to water in the proportion of 100 to 112 it does not change in specific gravity ; it remains liquid, and requires a temperature below 0 for its congelation. This acid is volatile, and when poured from a phial its odour, which is similar to that of vinegar, is diffused through the room. It is inflammable and takes fire on the application of a flame. Exposed to the air in its concentrated state, it attracts a portion of its aqueous vapour.

According to M. M. Gay-Lussac and Thenard, it is composed of

Carbon	-	-	-	-	-	50.224
Hydrogen	-	-	-	-	-	5.629
Oxygen	-	-	-	-	-	44.147
						<hr/>
						100.000

or

Carbon	-	-	-	-	-	50.224
Oxygen and hydrogen in the ratio to compose water	}					46.911
Oxygen in excess						-
						<hr/>
						100.000

Berzelius states its composition at

Carbon	-	-	-	-	-	46.83
Oxygen	-	-	-	-	-	46.82
Hydrogen	-	-	-	-	-	6.35
						<hr/>
						100.00

DCCCXLI. Acetic acid enters into combination with the salifiable bases, and forms salts which have received the name of Acetates.

1. *Acetate of ammonia.* This salt, which is formed by saturating acetic acid with ammonia, is so soluble that it can be obtained crystallized only with great difficulty. Its crystals, when procured by sublimation, are long and slender prisms, of a cooling and somewhat sweetish taste, deliquescent, fusible at 170° , and decomposable by heat. Distilled vinegar saturated with ammonia has long been used in medicine by the name of *Spirit of Mindererus*.

2. *Acetate of potash.* Formed by dissolving carbonate of potash in distilled vinegar, evaporating to dryness, melting it, then dissolving in water, filtering, and evaporating to a sufficient degree; it is usually in the shape of masses composed of thin plates, of fine pearly lustre, of a sharp taste, soluble in an equal weight of water, likewise in alcohol in smaller proportion, extremely deliquescent, and decomposable in a strong heat, producing carbonic oxide and carbonic acid gases, charcoal, empyrenumatic oil, and carbonate of potash. It contains about 51 parts of acetic acid, and 49 of potash. It has been known in medicine by the names of foliated tartar, and digestive salt of Sylvius.

3. *Acetate of soda.* This salt prepared by a process similar to the above, has properties very analogous. Its crystals are striated prisms, soluble in water and alcohol, but not deliquescent. It is decomposed in a high heat.

4. *Acetate of barytes* has a bitter taste, and crystallizes in fine prisms, which are soluble in water, and efflorescent in the air. Acetate of strontian differs from that of barytes in being permanent in the air, and less soluble in water. Acetate of lime crystallizes in silky fibres, of the specific gravity of 1.005, very soluble in water and alcohol, and permanent in the air. It contains an excess of acid, and hence its taste is sour and bitter. The acetate of magnesia, when evaporated, produces a gelatinous mass, soluble in water and alcohol, and having a sweetish taste.

5. *Acetate of iron.* Acetic acid oxidizes iron and combines with its oxide; the salt may likewise be formed by dissolving sulphuret of iron in acetic acid. Its crystals are green, of a prismatic form, of a sweetish astringent taste, very soluble, and composed of the acid in combination with the protoxide, forming a *protacetate* of iron. By exposing this salt to heat or to the air, the protoxide is converted into peroxide, and the salt into a *per-acetate*, which is a brown coloured liquid, incapable of crystallizing, and deliquescent. It is employed by calico-printers.

6. *Acetate of manganese* is in the form of reddish coloured, translucent, rhomboidal tables, of an astringent metallic taste, permanent in the air, soluble in water, and composed according to John of 30 of oxide and 70 of acid and water.

7. *Acetate of tin.* This salt may be formed by mingling together solutions of muriate of tin and acetate of lead. It may be obtained in small crystals. When vinegar is allowed to stand long in contact with tin vessels, it dissolves a small portion of the metal, as well as of lead, if that metal be present.

8. *Acetate of zinc* is prepared for medicinal purposes by mixing solutions of acetate of lead and sulphate of zinc. The acetate remains in solution. It crystallizes in rhomboidal plates of a greasy lustre, permanent in the air, very soluble in water, and of an astringent metallic taste. A crystal of this salt, when thrown into the fire, burns with a blue flame.

9. *Acetate of copper.* Of this compound there are two varieties, the acetate and the sub-acetate.

1. *Sub-Acetate. Verdigris.* For commercial purposes this substance is prepared by exposing sheets of copper to the action of acetic acid produced during the fermentation of husks of grapes, the two being stratified in large jars which are loosely covered. After 3 or 4 weeks the copper becomes covered with a greenish crust, which is scraped off, put into bags of skins, and dried. Its colour is green with a shade of blue; it is opaque, and destitute of crystalline form. It is

composed according to Proust of 43 parts of acetate of copper, 27 of black oxide, and 30 of water. Hence when put into water nearly $\frac{1}{2}$ dissolves.

2. *Acetate*. When verdigris is dissolved in acetic acid and crystallized, it assumes the form of prisms or more generally of quadrangular pyramids, translucent, of a fine bluish green colour, of a nauseous metallic taste, sparingly soluble in water, and efflorescent in the air. Its solution is decomposed by sulphuretted hydrogen, a sulphuret of copper being precipitated. When distilled at a strong heat, it yields acetic acid. This salt is composed, according to Proust, of

Acetic acid and water	-	-	-	-	61
Oxide of copper	-	-	-	-	39
					<hr/>
					100

These acetates, it is well known, are employed in the art of painting, and the last in dyeing. The latter is called in commerce by the improper name of *distilled verdigris*.

10. *Acetate of lead*. *Sugar of lead*. When lead is acted upon by boiling vinegar, or when rolls of this metal are put into large pots containing vinegar and are exposed to the heat of a fermenting mixture for some weeks, a white crust forms upon their surfaces, which when scraped off and powdered, constitutes white lead, or cerusse. It has generally been considered as a sub-carbonate of lead. When distilled vinegar is boiled in successive portions upon cerusse, until the latter is dissolved, and the solution is evaporated to the consistence of honey, it yields on cooling a crystallized substance, which is the sugar of lead of commerce, the super-acetate or binacetate of the chemists.

It is in the form of long and slender 4 or 6-sided prisms, often grouped and radiating from a centre, and when more care is employed may be obtained in large and flattened 4-sided prisms bevelled at the extremities. Its taste is sweetish and astringent, its colour white with a shade of yellow; it is

efflorescent, soluble in about 3 times its weight of water at 60°, and renders even distilled water slightly turbid, probably from its being partially decomposed. With well-water it forms a white and opaque liquid from which a white powder is soon precipitated, consisting of sulphate and carbonate of lead. It is decomposed by the alkalies, and alkaline earths, and by all those salts with the acid of which the oxide of lead is capable of producing an insoluble compound. Suphuretted hydrogen is a very delicate test of its presence, forming a dark brown precipitate, and hence a solution of that gas is employed to detect the presence of sugar of lead in the weak bodied wines, to which the salt is added to conceal their acid taste. The same effect is produced by the hydrosulphurets, but in the last case the precipitate is not of so dark a colour. It has been sufficiently demonstrated by the experiments of M. Thenard, of Dr. Bostock, and of Professor Berzelius, that there exists in this salt an excess of acid; hence it is to be considered as a *super-acetate*.

The *neutral acetate* of lead may be formed by boiling together 100 parts of sugar of lead and 150 of dry litharge free from carbonic acid, by which the redundant acid in the former is neutralized. Its crystals are thin plates less sweet to the taste and less soluble in water than the super-acetate. Its solution is precipitated readily by carbonic acid. It is soluble in distilled vinegar and the solution when evaporated affords needle-form crystals.

There is a preparation of acetic acid employed in medicine, which goes by the name of Goulard's Extract of lead, and which is prepared by boiling distilled vinegar to saturation on litharge. This liquid has been proved by Dr. Bostock to be a solution of the neutral acetate.

The super-acetate, according to the analysis of Berzelius, is composed of

Acetic acid	-	-	-	-	-	26.97
Oxide of lead	-	-	-	-	-	58.71
Water	-	-	-	-	-	14.32
						<hr/> 100.00

The neutral acetate of

Acetic acid	-	-	-	-	-	86.77
Oxide of lead	-	-	-	-	-	13.23
						<hr/>
						100.00*

11. *Acetate of mercury.* Acetic acid combines with both oxides of mercury. When a warm solution of acetate of potash is poured into a solution of mercury in diluted nitric acid, made without the application of heat, a mutual decomposition takes place, acetate of mercury and nitrate of potash are formed, and as the liquid cools the mercurial salt separates crystallized in small plates of a silvery lustre, of an acrid taste, insoluble in alcohol, and requiring 600 parts of water for its solution. It is a compound of acetic acid and protoxide of mercury, and is employed for medicinal purposes.

The per-acetate of mercury may be prepared by dissolving the peroxide in acetic acid. It is incapable of crystallizing, and is decomposed by water, a salt with a great excess of acetic acid remaining dissolved while a sub-salt is separated, resembling the sub-sulphate of mercury. This per-acetate has an acrid taste and is more soluble in water than the acetate. It is likewise soluble in alcohol.

Acetic acid has no effect upon metallic gold, silver, or platinum, but it dissolves their oxides.

Several of the proximate principles of vegetables, such as resins, gum-resins, camphor, essential oils, gluten, &c. are soluble in this acid.

Acetic Ether.

DCCCXLII. Acetic ether was discovered in 1759 by Count de Lauragnis. It may be prepared by mixing together in a tubulated retort, connected with a receiver kept cold, 100 parts of strong alcohol, 63 of concentrated acetic acid,

* Annals of Philosophy, vol. v. p. 175.

and 17 of sulphuric acid, applying heat until about 125 parts of liquid have distilled over. This liquid may be purified by putting it into a bottle with a little caustic potash and allowing them to remain in contact with occasional agitation, for half an hour. It separates into two portions, the upper stratum consisting of pure ether. The rationale of the process, at least so far as regards the sulphuric acid, is very simple, for it operates merely by abstracting water from the other materials.

Another economical method of forming this ether is to introduce into a retort 3 parts of dry acetate of potash, 3 of very strong alcohol, and 2 of concentrated sulphuric acid, and distilling to dryness. The liquid thus obtained is to be mixed with $\frac{1}{5}$ its weight of sulphuric acid, and redistilled. The product will be equal to the alcohol employed.

Acetic ether is colourless and transparent, of a peculiar taste, and of an odour similar to that of a mixture of acetic acid and sulphuric ether. Its specific gravity is 0.866. It has no effect on vegetable colours. Exposed to heat it boils at the temperature of 128° . At 63° water dissolves $\frac{1}{7}$ of its weight of this ethereal fluid, and acquires its peculiar taste and odour, but it loses them on the addition of half its weight of potash, and the ether is completely decomposed. If distilled in this state, alcohol passes into the receiver, and acetate of potash remains in the retort. Acetic ether is inflammable, it burns with a yellowish white flame and gives out acetic acid.*

It is soluble in alcohol, and is a solvent of oily substances.

The uses of acetic acid, it will be seen from what has been said, are numerous and important. In the form of vinegar it is employed as a condiment, as an agreeable substance for fumigations, and for many other purposes in medicine.

Putrefactive Fermentation.

DCCCXLIII. When the vital actions of a plant have ceased another series of combinations commences, which termi-

* Thenard. *Traité de Chimie*, t. iii. p. 291. 2 edit.

nates only in its entire disorganization. The vegetable substance becomes covered with mould, various gases are evolved, and the mass crumbles to the earth, leaving only a portion of the carbon and the salts which it previously contained. The gases disengaged are the different species of carburetted hydrogen, and carbonic acid, and the odour exhaled during this process is in general by no means so offensive as that which characterizes the putrefaction of animal substances; a circumstance which is owing to the absence of azote, for when this element is present there is little difference in this respect, as is exemplified in the spontaneous decomposition of the cabbage.

The circumstances which favour this disorganization of vegetables, are moisture, a moderate temperature, and the presence of atmospheric air. When a vegetable substance is excluded from the air, it gives out carburetted hydrogen, but when the air is freely admitted, besides this compound, it evolves carbonic acid. When the plant is thus destroyed, the remaining mass is *mould*, and this constitutes the fertilizing part of soils. Hence, when new countries are cultivated, when a soil, upon which the forest has for ages deposited its leaves, and withered trunks, and formed a thick stratum of vegetable mould, is first opened to the seed of the husbandman, the growth is rapid and luxuriant, and his labours are rewarded with a bounteous harvest. The colour of mould is nearly black, a certain part of it is soluble in water and in alcohol, and possesses the properties of extractive matter. It is no doubt the case, that this part alone constitutes that portion of the food of plants which is imbibed by the roots. Exposed to the air, it yields carburetted hydrogen and carbonic acid, which may likewise be decomposed by living vegetables, and hence results the benefit of turning or ploughing the soil.

BOOK II.

OF ANIMAL BODIES.

DCCCXLIV. THE composition of animal bodies is more complicated than that of vegetables. Besides the three elementary substances, oxygen, hydrogen, and carbon, which are common to both classes of organic beings, animal matter contains a large proportion of azote, and smaller quantities of phosphorus and sulphur. Some of the earths and metals likewise frequently enter into its composition. It is impossible to decide in what modes these elements are combined, for the most that the chemist has been able to effect has been the conversion of one substance into another. He has not yet succeeded in uniting the ultimate elements of matter in such a way as to produce a body similar to organic substance.

DCCCXLV. From the number of substances which compose animal products, and probably from the manner in which they are united, they are more susceptible of decomposition than the proximate principles of vegetables; and when this spontaneous decomposition takes place, it is analogous to the putrefactive process already mentioned. In order to arrive at the knowledge of their ultimate elements, they are subjected to decomposition by the aid of heat, which process is called *destructive distillation*. The products usually obtained are an aqueous liquid, empyreumatic oil, charcoal, carburetted hydrogen, and carbonic acid gases, hydrocyanic acid, carbonate of ammonia, and minute quantities of some of the saline combinations. In other cases, where it is required to find the proximate principles, the method by solution in some liquid and the application of various reagents is employed.

In describing this class of bodies, the subject will be divided into three chapters; the first will be devoted to the proximate

principles of animals, the second to the solids and fluids, which they compose, and the third, to the phænomena of their spontaneous decomposition.

CHAP. I.

OF THE PROXIMATE PRINCIPLES OF ANIMALS.

These are Gelatine, Albumen, Fibrin, Mucus, Picromel, Urea, Cantharadin, Cochinealin, Oily and Resinous substances, Acids, Sulphur, Phosphorus, and Saline Compounds.

SECTION I.

Of Gelatine.

DCCCXLVI. Gelatine exists in large proportion, and constitutes an important proximate principle of animal bodies. It may be prepared for experiment by boiling the isinglass of commerce in 30 or 40 times its weight of water, until it is dissolved, straining that liquid while hot through fine linen, and allowing it to cool; or by boiling a portion of the recent skin of an animal in water, after all its oily and colouring matter has been removed. If the water have dissolved any considerable proportion, it will be found on cooling to have assumed the consistence of a jelly. The substance which gives to water this property is gelatine. It may be obtained in a pure and solid state by evaporating the solution. The properties of this substance have been accurately examined by Mr. Hatchett,* and Dr. Bostock.†

DCCCXLVII. Gelatine is a transparent and colourless solid, of a vitreous fracture, and of a specific gravity greater than that of water. It is insipid to the taste, destitute of odour, and incapable of affecting vegetable colours. It suffers no change on exposure to the air, if dry, but it slightly attracts moisture, and undergoes a slow alteration.

* Philosophical Transactions, vol. xc.

† Nicholson's Journal, vol. xiv. and xxi.

Gelatine softens in cold water, but dissolves readily in that liquid at a boiling heat. The solution is slightly opaque and opal coloured, and its disposition to gelatinize is so great that a soft and tremulous jelly will be formed when the proportion, according to Dr. Bostock, is only 1 of gelatine to 100 of water. It may be recovered unaltered by evaporation. On long standing, this solution becomes mouldy and acquires a putrescent odour.

Gelatine in solution is not affected by many reagents. It is precipitated by nitrate of mercury and muriate of antimony in the form of a copious white flaky matter.* Its solution is likewise rendered turbid by alcohol and ether, in which liquids it is insoluble. The best test of gelatine is solution of tannin. When they are mingled, a thick white precipitate is immediately formed. Some precautions however are requisite before dependence can be placed upon the result of this experiment.

Gelatine is frequently accompanied with albumen, which is soluble in water and capable of forming an insoluble compound with tannin. Hence albumen, if it be present, must be previously removed by the use of corrosive sublimate.

Solution of gelatine is rendered opaque and milky by chlorine gas, and a white precipitate gradually falls. When dry it is dissolved by the acids, and by the alkalies, but is not affected by the earths.

DCCCXLVIII. On exposure to heat, it swells up, grows black, emitting vapours of a disagreeable odour, and leaving a coaly mass. By destructive distillation, it yields the usual animal products. According to the analysis of Gay-Lussac and Thenard, gelatine is composed of

Carbon	-	-	-	-	-	47.881
Hydrogen	-	-	-	-	-	7.914
Oxygen	-	-	-	-	-	27.207
Azote	-	-	-	-	-	16.998†
						<hr/>
						100.000

* Dr. Thomson.

† *Recherches Physico-Chimiques*, t. ii. p. 336.

DCCCXLIX. Gelatine constitutes a large proportion of the soft animal solids, such as flesh, skin, cartilage, tendon, ligament, membranes, and bone. It is the presence of this substance which gives the property of gelatinizing to water in which animal bodies have been boiled. Hence it may be considered as one of the most nourishing of the principles derived from the animal kingdom.

DCCCL. Several preparations of gelatine are known in commerce, such as isinglass, glue, and size; and when combined with tannin it constitutes leather.

1. *Isinglass* is prepared from the air-bladders and stomachs of the sturgeon and other species of *Accipenser*. They are washed clean, the external membrane is separated, then made into rolls and dried in the air. It is white and semi-transparent, soluble in hot water, and imparting to it the property of gelatinizing on cooling. A coarser kind of isinglass is formed from different parts of fishes, by boiling them in water, removing the impurities, allowing it to gelatinize, then melting it into flat masses, and allowing them to dry. Isinglass is employed for a variety of useful purposes. The finer kinds are consumed as food, and the coarser for clarifying liquids, forming court-plaster, stiffening linen, &c.

2. *Glue*. To form this substance, the refuse of animal substances, such as the parings of hides, pelts from furriers, hoofs and ears of the domestic animals, are digested in lime-water for the purpose of freeing them from their oleaginous matter; they are then boiled in water, the impurities as they rise being removed, a little alum or quick-lime being added; the liquid is then strained through baskets, the sediment, if there be any, is allowed to subside, and the decoction is again boiled to a sufficient consistence. It is poured into large frames, and when sufficiently gelatinized, is cut into square cakes, which by means of a wire, are sub-divided into thin tables; these are placed upon a net to dry in the open air. The best glue is hard and brittle, of a dark brown colour and free from black spots. Glue made from parts of old animals is said to

be stronger than that from the young. When glue is soluble in cold water it is a proof that it wants strength.*

3. *Size* is a finer kind of glue, which is manufactured with more care from eel-skins, vellum, parchment, and the skins of the smaller domestic animals. It is inferior in strength to glue, and being transparent is used by linen manufacturers, paper-makers, gilders, &c.

4. *Leather*. This important article is a true chemical compound of gelatine and tannin. The skins of animals are composed principally of gelatine in a state of organization, and the process of tanning consists in converting it into a substance which is insoluble in water, and incapable of the putrefactive fermentation. This is done by submitting the skins, previously freed from the hair and oily or fatty matter, to the action of astringent vegetables, and particularly of infusions of oak-bark. They are first immersed in a weak infusion, but as the combination of the gelatine of the skin with the tannin of the bark takes place, they are removed to those which are stronger, until they are exposed to the strongest.

This process requires some months for its completion, and the dry skin increases about one third in weight. The colour of the leather depends upon the vegetable substance employed. Thus skin tanned with oak-galls is much paler than skin tanned with oak-bark, which contains a brown extractive matter, and leather made from catechu is of a reddish tint. The slower the operation of tanning, the more perfect is the leather. Hence the method proposed by Seguin will not probably yield an article of very good quality. He asserts that skins introduced into the strongest possible infusion of tannin may be converted into leather in a few days; but in such cases a combination between the gelatine and the tannin is formed at and immediately below the surfaces in contact, which prevents the infusion from penetrating into the internal substance of the skin, and it is but partially converted into leather. This compound does not dissolve, but it is

* Clennel. Thomson's Chemistry, vol. iv. p. 405.

rendered soft, pliable and somewhat elastic by maceration in water.

SECTION II.

Of Albumen.

DCCCLI. This substance, like gelatine, exists in abundance in the animal system, and constitutes a very important proximate principle. It is similar in properties to the white of an egg ; hence the same term has been applied to both.

In its liquid state, albumen is a transparent, colourless, and glairy fluid, insipid to the taste, and destitute of smell. Exposed to a moderate heat, so that its water, of which it contains a large proportion, may be slowly evaporated, it is converted into a transparent solid, brittle, and of a vitreous fracture. Albumen is soluble in water, and the solution may be formed by dropping the white of an egg into water, agitating the mixture, and afterwards straining. The solution is slightly turbid and opalescent, and in consequence of the presence of soda, converts vegetable blues to a green. On exposure to heat, the albumen coagulates, and a cloudiness or opacity is produced, even when the proportion of albumen to water is as 1 to 1000. But if the proportion be as 1 to 12, then, according to Bostock, coagulation will not take place. This coagulation may likewise be produced without the aid of heat by several chemical agents, as for example, alcohol, ether, acids, and neutro-saline compounds. Nitric acid forms with albumen a copious yellowish precipitate, and is a delicate test of its presence in solution. Albumen unites with phosphoric and acetic acids, without being coagulated. The precipitate produced by alcohol is said to be more soluble than that by the acids. Albumen is dissolved by the alkalis, and particularly in their caustic state. When rubbed with potash, the odour of ammonia is given out, a gelatinous mass is formed, which after a while becomes solid and transparent. When albumen is mingled with solution of caustic

potash, and muriatic acid is poured into the solution, the albumen coagulates, but no such effect takes place if the alkali be in the form of carbonate; the reason is, that in the first case heat is evolved, but little or none in the second.*

DCCCLII. Liquid albumen is precipitated by chlorine and by a great number of the metallic salts. Of these, the bichloride or corrosive muriate of mercury is the most convenient and delicate. According to the experiments of Dr. Bostock, this salt will form a white precipitate in a solution which contains only $\frac{1}{2000}$ part of albumen. He has likewise found Goulard's extract, and nitrate of silver to produce the same effect, as likewise tannin, though more slowly; but the two former occasion precipitates in solutions of other proximate principles of animals, and are not therefore to be depended upon as tests.† He proposes that more of the solution of the sublimate than is necessary to saturate the albumen present, should be added, and then, on the application of heat, a coagulum will be formed, which will contain $\frac{5}{7}$ of its weight of albumen.

DCCCLIII. When glairy albumen is exposed to the temperature of 165°, it grows white and opake around the edges, the whole mass swells, and is converted into a white solid, insipid and inodorous. In this state it is insoluble in water, hot or cold, though it is softened by maceration in that liquid. According to Mr. Hatchett, it is much less liable to spontaneous decomposition than liquid albumen. It is dissolved by concentrated nitric acid, but if the acid be diluted and the albumen be long in contact with it, the acid acquires a deep yellow tinge, and the albumen is converted into a substance possessing the properties of gelatine.‡ The same chemist ascertained that coagulated albumen was soluble in a hot solution of potash, ammonia being at the same time disengaged, a soap was formed, which was soluble in water and decomposable by an acid.

* Thenard. Chimie, iv. 467. † Nicholson's Journal, xi. 247.

‡ Philosophical Transactions for 1800, p. 376.

It is difficult if not impossible in the present state of our knowledge to account for the coagulation of albumen. It is independent of the air, and hence has no connexion with the absorption of oxygen. Its weight after coagulation is the same as before, and it is not therefore owing to the disengagement of water or of any of its elements. It seems to change only in the state of cohesion of its particles, but how this is produced it is impossible to say.

DCCCLIV. When albumen is distilled in close vessels, it yields the usual products. In the open air, it blackens as it becomes heated, exhales a disagreeable odour, and leaves a residue of coal. Analyzed by M. M. Gay-Lussac and Thenard, it afforded of

Carbon	-	-	-	-	-	52.883
Oxygen	-	-	-	-	-	23.872
Hydrogen	-	-	-	-	-	7.540
Azote	-	-	-	-	-	15.705*
						<hr/>
						100.000

There are some other substances however found in albumen or its products. It is well known that silver acquires a yellow colour when brought into contact with an egg, and it has been found by Parmentier and Deyeux, that when albumen was triturated with solution of nitrate of silver, and digested in water, one of the products was sulphuret of silver. Hence sulphur, probably in combination with hydrogen, may be considered as one of the component parts of albumen. Besides this, phosphate of lime has been discovered in the ashes of this substance, and as albumen has the property of turning vegetable blues to a green, it must contain an alkali, which has been proved to be sub-carbonate of soda.

Albumen is found in the osseous and muscular apparatus, and enters into the composition of horn, cartilage, hair, nails, and many membranous parts.

* *Recherches*, t. ii. 332.

In the arts albumen is employed for the purpose of clarifying liquids, and it is albumen which gives this property to the whites of eggs and the blood of animals. It is a nutritious substance.

SECTION III.

Of Fibrin.

DCCCLV. A substance obtained from blood has long been known to physicians and physiologists by the name of *buffy coat*, or *coagulable lymph*, but its chemical properties were not investigated with much precision until its examination was undertaken by Mr. Hatchett. It may be procured from that liquid as it flows from a vein by beating it with a stick, to which filaments of a red colour will adhere, and may be rendered white by washing with cold water.

The *crassamentum* of the blood, when tied up in a cloth, and washed with large quantities of cold water, will likewise yield this principle, which is recognised by chemists by the name of Fibrin. Mr. Hatchett procured it from muscle, by macerating a portion of lean beef in water for several days, then boiling it for some time in successive portions of water, pressing the mass, and drying it at a heat not exceeding 212° .*

DCCCLVI. Fibrin is white and fibrous in its texture, insipid, inodorous, soft, and somewhat elastic. It does not act upon vegetable blues. It is insoluble in cold water, and according to Mr. Hatchett it may be kept under the surface of that liquid even for 2 months without becoming putrid. According to M. Gay-Lussac, when put into water in an open vessel, the water being occasionally renewed, it almost entirely disappears, leaving, when it is fat, a species of fatty matter.† Boiling water dissolves only a small portion, and when infusion of galls is added to its filtered solution, it

* Philosophical Transactions for 1800.

† Annales de Chimie, et de Physique, t. iv. p. 71.

produces a white and dense precipitate. If fibrin be merely moistened with water, it grows soft, enlarges in bulk, and putrefies. When long in contact with alcohol of the specific gravity of 0.81, it produces a matter resembling *adepecire*, of a strong and disagreeable odour, which may be precipitated from the spirit by water.

DCCCLVII. Fibrin is acted upon by the acids. It is decomposed by sulphuric acid, and yields carbon and acetic acid. When boiled with diluted nitric acid, azotic gas is given out, and a fatty matter is disengaged. The acid acquires a lemon yellow colour. When digested in strong nitric acid, it is converted into a pale yellow mass, which is soluble in caustic alkali, and is said by Berzelius to be a compound of the acid and fibrin. The azote disengaged in the first case has been affirmed by Berthollet to proceed entirely from the decomposition of the animal substance, the acid experiencing no change. In this process however a quantity of nitric oxide is frequently produced, and carbonic acid in small proportion passes into the receiver. When digested in diluted muriatic acid, fibrin is ultimately converted into a gelatinous mass. Berzelius states that the two substances combine in two proportions; one neutral, which is soluble, the other with excess of acid, which is insoluble. Fibrin is completely soluble by the aid of heat in acetic acid, provided water be added after the combination have taken place. The solution is transparent, of a disagreeable taste, and yields a precipitate of a white colour by prussiate of potash, an alkali or the mineral acids.

Fibrin becomes transparent and gelatinous, and then dissolves in the caustic alkalies. The solution is decomposed by any acid. If the alkaline solution be hot, the fibrin is decomposed and ammonia is disengaged.

DCCCLVIII. When exposed to heat, it partially melts, then shrivels, exhales a disagreeable odour, and leaves a spongy charcoal. By distillation it produces the usual products. According to the experiments of Gay-Lussac and Thenard it is composed of

Carbon	-	-	-	-	-	53.360
Oxygen	-	-	-	-	-	19.685
Hydrogen	-	-	-	-	-	7.021
Azote	-	-	-	-	-	19.934*
						<hr/>
						100.000

Besides these, its incineration produces carbonate and phosphate of lime, and phosphate of soda.

Fibrin, as it constitutes the basis of the muscular parts, exists in large proportion in animal bodies, and is to be considered as a very nutritive substance.

SECTION IV.

Of Mucus.

DCCCLIX. There is much discordance of opinion among chemists respecting the existence of a peculiar animal principle which has received this name. Berzelius affirms that there is no such substance as the mucus of the animal fluids; that what is thus called, is in reality lactate of soda, mixed with the animal matter which always accompanies it.† Dr. Bostock, on the contrary, thinks he obtained mucus from saliva, and from the liquid of the oyster. According to this ingenious chemist, if saliva be evaporated to dryness, and be redissolved in water and filtered, the solution will contain a very large proportion of mucus. When solid, it is semi-transparent, and has a considerable resemblance to gum, both in its solubility in water and its adhesive property. It is insoluble in alcohol, is incapable of coagulating, but when sufficiently concentrated will gelatinize, is not precipitated by galls nor corrosive sublimate, but affords with Goulard's extract a copious white précipitate. It yields the usual animal products by distillation. Berzelius has given the following analysis of saliva.

* *Rechères*, t. ii. p. 330.

† General view of the Composition of Animal Fluids. *Medico-Chirurgical Transactions*.

Water	-	-	-	-	-	-	992.9
A peculiar animal matter	-	-	-	-	-	-	2.9
Mucus	-	-	-	-	-	-	1.4
Alkaline muriates	-	-	-	-	-	-	1.7
Lactate of soda and animal matter	-	-	-	-	-	-	0.9
Pure soda	-	-	-	-	-	-	0.2
							<hr/>
							1000.0

Fourcroy and Vanquelin examined the fluid scented by the nostrils. It exhibited several of the characters ascribed by Dr. Bostock to mucus. They found in it besides water and mucus, small quantities of muriate and carbonate of soda, and phosphates of soda and lime.* The analysis of nasal mucus by Berzelius is as follows :

Water	-	-	-	-	-	-	933.7
Mucous matter	-	-	-	-	-	-	53.3
Muriates of potash and soda	-	-	-	-	-	-	5.6
Lactate of soda with its accompany- ing animal matter	}						- 3.0
Soda	-	-	-	-	-	-	0.9
Albumen and animal matter, insoluble in alcohol, but soluble in water, with a trace of phosphate of soda.	}						- 3.5
							<hr/> 1000.0

The chemical composition of the liquid of tears is analogous to that of nasal mucus.

DCCCLX. Lymph is a transparent, glairy liquid, circulated in the lymphatic vessels, and according to Mr. Brande, in the thoracic duct of animals which had been denied food for 24 hours. It seems, according to his experiments, to approach more nearly to mucus than to any other animal substance.

* Fourcroy's Chemistry, vol. ix. p. 432.

SECTION V.

Of Picromel.

DCCCLXI. Picromel, so named from its taste, is a substance found in the bile of animals.

It may be obtained, according to Thenard, by pouring into ox-bile a solution in excess of sugar of lead, which precipitates all the colouring matter, together with the phosphoric and sulphuric acids of the phosphate and sulphate of soda. The liquid is then filtered and there is added Goulard's extract of lead, a precipitate in white flocks immediately forms, which are to be collected, washed with water, and dissolved in distilled vinegar. The oxide of lead in the substance may then be separated by transmitting through the solution a stream of sulphuretted hydrogen gas, the liquid is again filtered, and exposed to evaporation, by which the acetic acid is driven off, and the picromel is obtained pure.

DCCCLXII. It is a white substance of the consistence of thick turpentine, of a taste at first acrid and bitter, afterwards sweet,* of a nauseous odour, and specifically heavier than water. When heated it loses its viscosity, swells up and is decomposed, yielding but very little carbonate of ammonia. It is deliquescent, and very soluble in water; it likewise dissolves in alcohol. When heated gently with the diluted mineral acids, it forms viscous liquids, which are not decomposable by the alkalies nor many of the salts. It is precipitated by nitrate of mercury, subacetate of lead, and the salts of iron. It is not affected by infusion of galls.

The most remarkable property of picromel is its power to combine with the acids in excess, and form a substance similar to resin, and which in fact has been mistaken for the resin of bile.

* Hence its name, from *πικρος*, bitter, and *μελι*, honey.

SECTION VI.

Of Urea.

DCCCLXIII. The name *Urée* was given by Fourcroy and Vauquelin to a peculiar substance obtained from urine, the properties of which they investigated. Several processes have been employed to procure this principle. Of these the following is said by M. Thenard to be the best. Evaporate urine by a gentle heat to the consistence of syrup, add by small portions at a time to this liquid an equal volume of nitric acid of 75°, agitate the mixture and immerse the vessel containing it in ice, in order to effect the precipitation of the acid nitrate of urea, wash the crystals with ice-cold water, drain off the water and press them between folds of blotting paper. They are then to be dissolved in water, and carbonate of potash is to be added in sufficient quantity to separate the nitric acid, the liquid is afterwards to be evaporated by a gentle heat nearly to dryness, very pure alcohol is to be poured upon the mass, the liquid filtered, and then concentrated by evaporation; the urea will be deposited as the solution cools.*

DCCCLXIV. Urea is a solid substance, and when pure is white, transparent, somewhat hard, and crystallized in laminæ or in 4 or 6-sided prisms. Its odour is urinous and disagreeable, its taste strong, acrid, and alkaline, it is somewhat viscid, and of a specific gravity superiour to water. It does not operate on vegetable colours. It is extremely deliquescent and soluble in water and in alcohol. On exposure to heat in a retort it melts, swells up, and then suffers decomposition, producing a large proportion of sub-carbonate of ammonia, a quantity of an extremely foetid gas, benzoic acid, oil, and hydro-cyanic acid, and leaves charcoal and muriates of soda and ammonia.

Its solution in water is brown, but when weak it is yellow. When left at rest for some time it undergoes spontaneous

* *Traité de Chimie*, t. iii. p. 476.

decomposition, there is found in the liquid acetate and sub-carbonate of ammonia, and during the process a very fœtid odour is exhaled.

DCCCLXV. When urea is boiled with diluted sulphuric, nitric, or muriatic acid, it is decomposed, and products are formed, the nature of which varies with the acid. With the first and second it produces carbonic acid and a sort of fatty matter of a blackish colour: with the third, the results are carbonic acid, hydro-cyanic acid, azote or oxide of azote; towards the conclusion the matter becomes thickened and finally inflames with a violent explosion.

DCCCLXVI. Urea has the property of combining with nitric acid and of forming a true chemical compound. It was found by Fourcroy and Vauquelin, that when nitric acid was poured into a strong solution of urea, there was an immediate precipitation of white and brilliant crystals, which were finally produced in such abundance as to render the liquid thick. These crystals are very acid to the taste, sparingly soluble in water, and decomposable by the salifiable bases. On exposure to heat it softens, then melts, produces an effervescence and finally an explosion, in consequence of the formation and subsequent sudden decomposition of nitrate of ammonia. Fourcroy and Vauquelin regarded this as a compound of nitric acid and urea, and the French chemists call it *acid nitrate of urée*.

Nitrous acid does not combine with urea, but a mutual decomposition takes place with violence, and the products are the same as those which result from the action of hot nitric acid upon this principle.

The aqueous solution of urea absorbs chlorine gas, a brownish flocculent matter is separated, and a gaseous fluid, consisting of carbonic acid and azote, is disengaged.

Urea dissolves readily in solutions of the alkalies, and ammonia is disengaged. The same effect is produced by rubbing urea and potash together, the mixture becomes brown, exhales ammonia and produces a sort of empyreumatic oil.

Solution of urea does not decompose any of the saline compounds, but it changes the form of their crystals, causing common salt to crystallize in octaedra, and sal ammoniac in cubes.

Infusion of galls has no effect on its aqueous solution.

DCCCLXVII. The destructive distillation of urea produces carbonate of ammonia, azotic gas, carburetted hydrogen, and charcoal. Hence it is obvious that it is a quadruple compound of oxygen, hydrogen, carbon, and azote. According to the analysis of M. Berard they exist in it in the following proportions.*

Oxygen	-	-	-	-	-	26.40
Azote	-	-	-	-	-	43.40
Carbon	-	-	-	-	-	19.40
Hydrogen	-	-	-	-	-	10.80
						<hr/>
						100.00

SECTION VII.

Of Cantharidin.

DCCCLXVIII. This name has been given by Dr. Thomson to the active matter of the Spanish fly, *meloe vesicatorius*; it was first procured in a separate state by M. Robiquet.

In order to obtain it, cantharides are to be boiled in water for some time; into the solution, evaporated to the consistence of syrup, is to be poured alcohol, and it is to be boiled in successive portions of that liquid, until all the soluble parts are abstracted. The alcoholic solution is then to be evaporated to dryness, the solid residue is to be put into a phial with sulphuric ether and frequently agitated, by which in the course of some hours a part will be dissolved. The ether is to be spontaneously evaporated, during which crystalline plates mixed with a yellow matter are deposited. Alcohol

* Thenard. *Traité de Chimie*, t. iii. p. 477.

poured upon the mass will dissolve the latter, but leave the former, which is then to be collected and dried between folds of blotting paper.

Cantharidin is in small micaceous plates, insoluble in water and cold alcohol, but soluble in boiling alcohol. It is less soluble in ether. It dissolves in oils and acts powerfully in this solution, or in its pure state as a vesicatory.*

SECTION VIII.

Of Cochinealin.

DCCCLXIX. This substance, the colouring matter of the insect employed in the formation of the beautiful scarlet dyes, was first obtained by Dr. John, and afterwards in a state of greater purity by M. M. Pelletier and Caventon. They found the substance of the insect to be composed of carmine, a peculiar animal matter, a fatty matter, and several salts. Their carmine is the same as John's cochinealin. It may be thus procured. Digest cocheneal in alcohol so long as it communicates colour, allow the liquid to evaporate spontaneously and a precipitate of a fine red colour will separate. Dissolve it in strong alcohol and mingle the solution with an equal bulk of sulphuric ether. The liquid will become muddy, and in a few days the carmine will be deposited in the form of a beautiful purplish red crust.†

DCCCLXX. Cochinealin is a substance of a fine purplish red, of a granular, semi-crystalline appearance, incapable of change on exposure to the air. It melts at the temperature of 122°, and if heated higher, is decomposed, yielding carburated hydrogen, a great deal of oil, a small quantity of slightly acid water, but no ammonia. It is very soluble in

* Thomson's Chemistry, 5th. edit. vol. iv. p. 436; or Annales de Chimie, lxxvi. p. 308.

† Annals of Philosophy, vol. xiii. p. 72; or Annales de Chimie et de Physique, t. viii. p. 250.

water, and a very small quantity of it gives a fine red tinge to that liquid. It is soluble in alcohol, but insoluble in ether. When pure, it is not precipitated from its solutions by the acids. In its aqueous solutions the acids produce at first a lively red colour, which changes to a yellowish tinge and finally to a full yellow. It is decomposed by the acids when they are concentrated. Its colour is discharged by chlorine. The alkalies produce in its solution a violet colour; the same effect takes place on the addition of barytes or strontian; but lime-water occasions a violet coloured precipitate. Alumina has a very strong attraction for carmine, and if when newly precipitated, it be put into its aqueous solution, the two substances unite to form a beautiful red lake, while the liquid becomes colourless and transparent. The colour of its solutions is likewise altered by several of the saline compounds, and from the results of their action the French chemists have drawn the conclusion, that the metals susceptible of different degrees of oxidizement act like the acids upon the colouring matter of cocheneal, when at a maximum of oxidation, but like alkalies when at a minimum or medium degree.

From the experiments of Pelletier and Caventon, cochenealin would appear to be a ternary compound of oxygen, hydrogen, and carbon.

Cochenealin or the colouring matter of the insect is employed in the formation of red dyes, and of the beautiful lake or pigment called *carmine*.

SECTION IX.

Of Animal Oil or Fat.

DCCCLXXI. The varieties of oil or animal fat which may be considered in this section agree with each other in many of their chemical properties. They are for the most part insipid, inodorous, insoluble in water, inflammable, and fusible at very moderate temperatures. They vary in consistence and are known by the names of oil, lard, tallow, and suet.

The nature of fat, &c. has been investigated with much precision both by Braconnot and Chevreul, and the conclusions to which they have arrived are curious and interesting. They appear to have proved that there exist two distinct substances in the various species of fat, the one fluid, and the other solid, and Chevreul has given to them the names of Stearin and Eleïn. He has likewise examined Spermaceti and obtained from it a peculiar substance, which he has called cetine.

*Stearine.**

DCCCLXXII. This principle was procured by heating hog's lard in seven or eight times its weight of strong alcohol in successive portions, until it was dissolved. The solution on cooling deposited a substance in the form of small needles, which to be purified was redissolved in alcohol, and crystallized several times in succession. In this process it is the stearine of the fat which precipitates while the elaine remains in solution. Braconnot's method to separate them was more simple, but less perfect. It consisted in pressing the fatty substance between folds of blotting paper, by which the elaine was absorbed and the stearine remained. But in order to obtain the latter in a state of purity, it will be necessary to have recourse to solution in alcohol.

DCCCLXXIII. Stearine thus obtained is in the form of needles, of a fine white, insipid, nearly inodorous, incapable of changing the colour of vegetable blue, insoluble in water, but soluble at a boiling heat in $55\frac{1}{2}$ times its weight of alcohol of the specific gravity of 0.816. Exposed to heat, it melts at the temperature of 102° . When heated with two thirds its weight of potash dissolved in 4 times its weight of water, it forms a soap, and is converted into margaric and olëic acids, and a fluid, which has a sweetish taste, and is soluble both in alcohol and water. This constitutes the sweet principle of oils of some chemists.

* From *στέαρ*, *suet*.

*Elaïne.**

DCCCLXXIV. When fat has been treated with alcohol as noticed above, elaïne remains dissolved in it, after the precipitation of the stearine. If the liquid be exposed to a freezing mixture, a small portion of stearine will be deposited, and the solution is then to be distilled, a little water being added towards the conclusion. It is a liquid of the appearance and consistence of white olive oil; it is colourless and transparent, insipid and inodorous; does not affect vegetable colours, nor dissolve in water. It is soluble in 32 times its weight of boiling alcohol specific gravity of 0.816. It is liquid at the temperature of 60°, but congeals at about 45°. Elaïne like stearine combines with the alkalies, but more readily, forming with them saponaceous compounds, and producing the sweet principle of oils.

The properties of elaïne are nearly the same from whatever fatty or oily substance it be obtained, but they differ in degree. According to Braconnot, butter consists of 60 parts of elaïne and 40 of stearine; hog's lard of 62 of the former to 38 of the latter, and marrow of 24 of the one to 76 of the other.

Cetine.

DCCCLXXV. Chevreul obtained this substance from spermaceti by exposing it to the action of strong alcohol at a boiling heat, and allowing the solution to cool, by which a peculiar matter was deposited.

Cetine is in the form of white crystallized plates, of a soft unctuous feel, brittle, destitute of taste and smell, and fusible at 120° Fah. It dissolves in about 16 parts of alcohol of the specific gravity of 0.816. It is capable of uniting with potash and of forming a saponaceous compound, which when decomposed by tartaric acid yields a fat acid of nearly the same weight as that of the cetine employed. If this acid be boiled

* From the Greek *ελαίον*, oil.

with barytes, the results are margarate and oleate of barytes and a fatty matter which is not acid.

We shall now advert to some of the animal compounds of stearine and elaine.

DCCCLXXVI. 1. *Hog's lard. Axunge.* This kind of fat is white, of a soft consistence, nearly destitute of taste and odour, incapable of acting on vegetable colours, insoluble in water, and fusible at the temperature of about 87° Fah. Exposed for some time to the air, it acquires a disagreeable odour and acrid taste, and is then said to be rancid. It is the consequence of the absorption of oxygen and the formation of *sebacic acid*. By washing the lard with water or alcohol, the acid is for the most part removed and its qualities are in a great measure restored. The same effect is produced in a shorter time by making use of a weak solution of pearlash. Fat is inflammable and may be employed for the production of artificial light, by the medium of a wick. When heated to 600° it undergoes decomposition, and its qualities are considerably altered. Its combustion produces water and carbonic acid.

It is partially decomposed by some of the acids. With nitric acid its action is peculiar, and it is converted into a substance, the properties of which are intermediate between those of wax and spermaceti. It decomposes the acid and combines with a portion of its oxygen.

Fat combines with some of the acidifiable bases, particularly phosphorus and sulphur. According to the analysis of Berard, it is composed of 69 parts of carbon, 9.66 of oxygen, and 21.34 of hydrogen.

The uses of this substance are doubtless familiar.

DCCCLXXVII. 2. *Suet. Tallow.* The colour and consistence of suet vary according to the animal from which it is obtained. When purified it is white, inodorous, insipid, insoluble in alcohol and water, harder and less fusible than

lard. It is said that candles made of suet or tallow are whiter, and of finer consistence when alum is employed in their manufacture.

DCCCLXXVIII. 3. *Train oil, and Spermaceti oil.* When oil is pressed from the blubber of the whale, it is thick and apparently mucilaginous; on standing for a time, an insoluble substance subsides, and the oil becomes clear, of a reddish brown colour, and fœtid smell. It may be purified by mixing it with a little sulphuric acid, then adding water, in consequence of which the oil of a lighter colour and less offensive odour will rise to the surface. Various other methods have been proposed for its purification, by the use of lime-water, alkalies, &c.

Spermaceti oil is much purer than the preceding species; on exposure to cold in considerable quantities, some foreign substance is precipitated, and with a portion of the oil congeals, while that which remains fluid is less coloured and purer. It is here called winter-strained oil.

Butter is likewise an animal fat, and its properties will be noticed under the head of Milk.

DCCCLXXIX. 4. *Animal oil.* A century or two ago, oil procured by the distillation of various animal substances was much employed in medicine, and endowed with many imaginary virtues. Empyreumatic oil, which is a very common product of destructive distillation, is this oil, mixed with, or holding in solution some principle which gives it a very disagreeable odour. It may be purified by repeated distillations. According to Dr. Thomson it is usually procured from the albuminous and gelatinous parts of animals. The horns are said to answer best. The product of the first distillation is to be mixed with water, and distilled with a moderate heat.

Dippel's animal oil is transparent and colourless, of a strong and rather aromatic smell, and almost as light and volatile as ether. It is soluble in small proportion in water, and changes vegetable blues to a green. It is likewise capable

of combining with the alkalies and acids, and of forming with them a kind of soap. It is inflamed by nitrous acid. Animal oil is soluble in alcohol, ether, and the oils. On exposure to the air it becomes brown.*

SECTION X.

Of Animal Acids.

We shall here treat only of those acids which are found ready formed in the animal œconomy, or which may be produced chemically by the operation of agents upon substances of an animal nature. These are Uric, Purpuric, Rosacic, Amniotic, Sacchilactic, Lactic, and Formic acids. There are a few to which we have already alluded, and which are formed from fatty matter. Such are Oleïc, Margaric, and Sebacic acids.

1. *Uric Acid.*

DCCCLXXX. Uric acid was discovered by Scheele, and its properties have been successively examined by Dr. Pearson, Dr. Wollaston, M. M. Fourcroy and Vauquelin, Dr. Henry, and Dr. Prout. It was at one time known by the name of lithic acid.

Uric acid is a constituent part of the urine, and forms the whole or part of the substance of some species of urinary calculi, particularly those, which, according to Marcet, are of a brownish or fawn colour, like mahogany, of a smooth though occasionally finely tuberculated surface, and formed of concentric layers, which are sometimes homogeneous, at others heterogeneous.†

From a calculus of this kind, uric acid may be obtained pure according to the process of Henry, by dissolving its powder in solution of potash, and adding to the liquid muri-

* Thomson's Chemistry, vol. iv. p. 440.

† Essay on Calculous Disorders.

atic or acetic acid, a white flaky precipitate will take place, which is to be collected, washed with a little ammonia to remove any acid remaining, then with warm water, and afterwards dried.

DCCCLXXXI. Uric acid is in the form of a powder, white with a tinge of yellow, harsh to the feel, destitute of taste and odour, and specifically heavier than water. It operates faintly upon delicate vegetable blues. It is sparingly soluble in water, requiring for its solution at 60° 1720 parts of that liquid, and at 212° 1150 parts, from the last of which it is precipitated in minute crystals as it becomes cool. This aqueous solution has no effect upon solutions of the earthy or metallic salts. It is insoluble in alcohol.

DCCCLXXXII. Uric acid combines with the salifiable bases, and forms salts called *urates*, which are white, powdery, sparingly soluble in water, and have much the appearance of the acid itself.

Uric acid is insoluble in solutions of alkaline carbonates, but it decomposes the hydro-sulphurets, and soap.

DCCCLXXXIII. It is acted upon by some of the acids, and particularly nitric acid. A solution may be formed which when concentrated, assumes a beautiful pink colour, that may be rendered nearly equal to that of carmine by the addition of water. This solution leaves a stain of the same colour upon the substance to which it is applied.

If the action between uric and nitric acids be promoted by heat, both will be decomposed and the results will be water, azotic, nitric oxide, and carbonic acid gases, hydro-cyanic acid, and nitrate of ammonia, and probably some of the vegetable acids.

DCCCLXXXIV. When uric acid is distilled, there passes over a little water holding in solution carbonate of ammonia, then follow dry carbonate of ammonia, and a sublimate of a peculiar nature, and a coal is left behind.

The sublimate was found by Dr. Henry to be a peculiar acid differing in properties from uric acid. It amounts to $\frac{1}{8}$

of the uric acid employed. It is of a yellow colour, bitter to the taste, soluble in water, which acquires the property of reddening vegetable blues, and volatile on exposure to heat. It unites in excess with the alkalis, and is soluble in nitric acid, but the solution does not stain.

According to the analysis of Berard, uric acid consists of

Azote	-	-	-	-	-	-	39.16
Carbon	-	-	-	-	-	-	33.61
Oxygen	-	-	-	-	-	-	18.89
Hydrogen	-	-	-	-	-	-	8.34
							<hr/>
							100.00

The constituents of uric acid are stated by Dr. Prout to be in the following proportions.

Carbon	-	-	-	-	-	-	34.286
Oxygen	-	-	-	-	-	-	22.857
Azote	-	-	-	-	-	-	40.000
Hydrogen	-	-	-	-	-	-	2.857
							<hr/>
							100.000

DCCCLXXXV. Dr. Prout has likewise examined the excrement of the *Boa Constrictor* and found it to consist altogether of uric acid. Since then, the urine of different species of serpents has been analyzed by Dr. John Davy, and been proved to be uric acid nearly in a state of purity. When first thrown out it is of a butyraceous consistence, but becomes hard on exposure to the air. The urine of lizards is of the same nature, while that of the alligator, besides uric acid, contains carbonate and phosphate of lime. The urine of turtles is liquid and contains flakes of uric acid, a little mucus and common salt, but no urea.

2. *Purpuric Acid.*

DCCCLXXXVI. This name has been given by Dr. Wollaston to a new acid, discovered by Dr. Prout, and formed by

the action of nitric acid upon uric acid. It may be obtained as follows. Dissolve pure uric acid in nitric acid, saturate the excess of the latter with ammonia, and slowly concentrate by evaporation. The liquid will become dark coloured, and soon deposit dark red crystals in abundance, which consist of purpurate of ammonia. These are to be dissolved in caustic potash, and heated until the colour disappears. If the solution be then dropped into diluted sulphuric acid, pure purpuric acid will be precipitated.

DCCCLXXXVII. Purpuric acid is in the form of a cream coloured powder, destitute of taste and smell, and incapable of acting on vegetable colours. It attracts no moisture from the air, but assumes a reddish colour, and is apparently converted into purpurate of ammonia. It is scarcely soluble in water, and perfectly insoluble in alcohol and ether. It dissolves in the strong mineral acids, in nitric acid with effervescence, and when heat is applied forms purpurate of ammonia. Chlorine produces the same effect. The only vegetable acid which dissolves it is the acetic when aided by heat. When heated, it neither melts nor sublimates, but acquires a purple colour, and then burns away without yielding any remarkable odour. When distilled, it produces carbonate of ammonia, a little prussic acid, and an oily looking fluid, while a pulverulent charcoal remains. Its constituents were found as follows.

Hydrogen	-	-	-	-	-	0.25
Carbon	-	-	-	-	-	1.50
Oxygen	-	-	-	-	-	2.00
Azote	-	-	-	-	-	1.75
						<hr/> 5.50

DCCCLXXXVIII. Purpuric acid combines with the salifiable bases, and most of these salts have a red colour. Purpurate of ammonia crystallizes in 4-sided prisms, which by transmitted light are of a dark garnet red, by reflected light

of a brilliant green. Most of the other purpurates possess the same peculiarity. The above salt is soluble in about 1500 times its weight of water at 60°; the solution has a slightly sweetish taste, no smell, and a fine crimson colour. Purpurates of potash and magnesia are much more soluble than those of ammonia and soda. Some of the metallic salts are more soluble than others.*

3. *Rosacic Acid.*

DCCCLXXXIX. This acid was discovered by Proust, and has been examined by Vanquelin and Vogel. It constitutes with uric acid the *lateritious sediment* which is deposited from the urine in fevers, and in paroxysms of the gout. It may be obtained by collecting this deposit, washing it with water, and treating it with boiling alcohol, which is afterwards to be evaporated to dryness. It is a solid of a lively cinnabar red colour, inodorous, but of a slight taste. It reddens tincture of turnsol. It is very soluble both in water and alcohol, combines with the salifiable bases, and forms with them soluble salts, and produces in solution of acetate of lead a light rose-coloured precipitate. It likewise unites with uric acid. By sulphuric and nitric acids, it is changed to a dark red powder, which exhibits the properties of uric acid. In solution of nitrate of silver it produces a fawn colour, and after 24 hours a precipitate of a bottle green colour. Independently of its colour, and of its action with the acids, Vogel observes that it does not differ essentially from uric acid.

Proust says it differs from that acid, in its solubility in water, in producing a violet precipitate in muriate of gold, and in its indisposition to crystallize.

4. *Amniotic Acid.*

DCCCXC. The amniotic liquid of the cow has been proved by Buniva and Vauquelin to contain a peculiar acid, to

* Annals of Philosophy, vol. xiii. p. 47.

which they have given the name of amniotic. It may be procured by slow evaporation. It is in the form of a white and brilliant solid, destitute of smell, but of a slight taste, and capable of reddening the delicate vegetable blues. It may be crystallized in needles, from its solution in hot water. It is sparingly soluble in cold water. Alcohol, particularly when heated, takes up a considerable proportion of this acid. It unites with the salifiable bases, and forms with them soluble salts which may be decomposed by most of the other acids, the amniotic acid being separated in the state of white powder. Its affinities are so weak that it is incapable of decomposing the alkaline carbonates, unless assisted by heat. It has no effect on the solutions of nitrates of silver, lead, and mercury. It is permanent in the air. Exposed to heat it swells up, is decomposed, affords sub-carbonate of ammonia, and leaves a voluminous charcoal. Amniotic differs from uric acid in being more soluble in hot water, in crystallizing in needles, and in being insoluble in boiling alcohol.

5. *Saclactic Acid.*

DCCCXCI. Saclactic acid was first formed by Mr. Scheele by repeatedly distilling nitric acid from the sugar of milk. It may be procured also by distilling 1 part of gum arabic with 2 parts of nitric acid.

It is in the form of a white and gritty powder, slightly acid to the taste, soluble in 80 parts of water at 212° , and depositing $\frac{1}{4}$ part on cooling. The solution changes the colour of vegetable blues. It unites with the different bases and forms saclactates, those with alkaline bases being soluble, while the earthy salts are insoluble. It combines with the metallic oxides, and produces in nitrates of silver, lead, and mercury, white precipitates.

According to the experiments of Gay-Lussac and Thenard, it consists of

Carbon	-	-	-	-	-	33.69
Oxygen	-	-	-	-	-	62.69
Hydrogen	-	-	-	-	-	3.62*
						<hr/> 100.00

There was consequently a large excess of oxygen.

Berzelius from his experiments concludes that it is composed of

Carbon	-	-	-	-	-	33.430
Oxygen	-	-	-	-	-	61.465
Hydrogen	-	-	-	-	-	5.105†
						<hr/> 100.000

This acid was formerly called the mucous or mucic acid.

6. *Lactic Acid.*

DCCCXCII. Lactic acid, obtained from sour milk by a very long process, as stated by Berzelius,‡ is when dry in the form of a smooth varnish, which attracts moisture from the air. It is very soluble in water, and produces a solution of a brownish yellow colour, and very acid taste. It is likewise soluble in alcohol; but is incapable of crystallizing from either of these solutions. On exposure to heat it boils, gives out an acid odour, and leaves a voluminous charcoal, which is incinerated with difficulty. On distillation it produces the usual animal products. It unites with the different bases and forms lactates which are exceedingly soluble in water and incapable of crystallization. With some of these bases it combines in more than one proportion.

According to Berzelius lactic acid exists in the urine, milk, and all the secretions of the animal body.

* *Recherches*, t. ii. 298.

† *Annals of Philosophy*, vol. v. p. 179.

‡ *Philosophical Magazine*, vol. xci. p. 241.

7. *Formic Acid.*

DCCCXCIII. This acid derived its name from being one of the products obtained by the distillation of a species of ant, the *formica rufa* of naturalists. It may be procured by infusing a quantity of red ants in three times their weight of water, and distilling the liquid in a silver or tin coppered still, until a burnt smell be perceived. The distilled liquid is then to be saturated with carbonate of potash, evaporated to dryness, decomposed by as much diluted sulphuric acid as is sufficient to combine with the potash, and distilling the materials to dryness. The liquid collected in the receiver is then to be rectified by a second distillation.

Formic acid is a liquid of a very sour taste, of a pungent odour, and of a specific gravity equal to 1.1168. It is incapable of crystallization. When heated in a retort it boils and evaporates without decomposition. It combines with water in all proportions, forms with alcohol an ether, and with the salifiable bases *formiates*, which are soluble in water, for the most part crystallizable, and differing in many respects from the acetates.

8. *Oleic Acid.*

DCCCXCIV. Oleic acid, according to Chevreul, is formed when fat is treated with potash and water, and remains in combination with the alkali. In order to separate it, the soapy liquid is evaporated until it becomes gelatinous on cooling, the mass is put into cold water, the liquid is again evaporated, and these processes are to be continued until the last solution is transparent. Into this is poured a concentrated solution of tartaric acid, which causes a precipitate of 48 or 50 parts of a white fatty matter, consisting of oleic acid with a little margaric acid.

This is to be heated with 12 parts of potash and 170 of water, afterwards boiled in water, and allowed to rest for several days, margaric acid in combination with the alkali

precipitates, and if tartaric acid be added to the residual liquid, the oleïc will be separated in a fluid and oily form.

DCCCXCV. Oleïc acid is a liquid of a yellowish white colour, fluid like oil at the temperature of 53° , but becomes solid and crystallizes in white needles at 43° Fah. It has a rancid taste and odour, and its specific gravity is 0.898. It reddens vegetable blues. It is insoluble in water, but soluble in all proportions in alcohol. Oleïc acid combines with most of the bases and forms oleates, some of which are neutral, some super-oleates, and others sub-oleates. The neutral oleates are so composed that the quantity of acid is to the quantity of oxygen in the oxide as 100 to 2.835.

There are only two oleates at present known which are soluble in water; these are the neutral oleates of potash and soda, and even these when the water is in large proportion are transformed into sub-oleates which precipitate, and neutral oleates, which remain in solution.

Oleïc acid is easily separated from its saline combinations.

It constitutes, according to Chevreul, in conjunction with margaric acid, the fat of dead bodies; and it enters into the composition of soap, the different species of which are all oleates and margarates of potash and soda in different proportions.

9. *Margaric Acid.*

DCCCXCVI. To obtain this acid 100 parts of purified hog's lard are boiled for 5 or 6 hours in a solution of 60 parts of caustic potash in 400 of water. The liquid is decanted, and the soapy mass is boiled in 600 parts of water, by which it is dissolved, and forms a gelatinous mass, which is to be diffused in a large quantity of cold water, and allowed to remain at rest for several days. A pearl-coloured substance separates which is super-margarate of potash. When this is treated with an excess of weak muriatic acid, the margaric acid separates, and after washing is to be put into boiling alcohol, from which it is soon deposited.

It is inferred that the change of margarine into margaric acid is effected by means of the potash, which causes the elements of that substance to combine in different proportions.

DCCCXCVII. Margaric acid is white, insipid to the taste, and of a slight odour, similar to that of white wax. Its specific gravity is less than that of water. It melts at the temperature of 133° , and forms a colourless and very limpid fluid, which crystallizes on cooling in beautifully white and brilliant needles. It has no effect when cold on tincture of turnsol, but when hot changes its colour to a red.

Margaric acid is insoluble in water, but very soluble in alcohol, 180 parts of it being dissolved at the temperature of boiling in 100 of that liquid of the specific gravity of 0.816. The acid is precipitated by the addition of water.

It combines with the alkalies and forms compounds which are called margarates. Some of these are neutral, while others contain an excess of acid. All the super-margarates are insoluble in water, as likewise the neutral margarates, with the exception of those of potash and soda; and even when these are treated with a great quantity of water, they are partially decomposed into neutral and super-margarates, the latter being precipitated.

Margaric acid is disengaged from these combinations by the greatest part of the acids.

As to the composition of these margarates it appears that, by the experiments of Chevreul, in the neutral margarates, the quantity of acid is to the quantity of oxygen in the oxide as 1 to 3; and as 1 to $1\frac{1}{2}$ in the super-margarates.

Margaric acid like the oleic enters into the composition both of the soft and the hard soaps. The saponaceous compounds in fact may be considered as margarates and oleates of potash, or soda.

10. *Sebacic Acid.*

DCCCXCVIII. When a quantity of lard or suet is distilled in an earthen-ware retort, there passes over a quantity of oil and grease, and a little acetic and sebacic acids. These are to be washed with water at a boiling heat, allowed to cool, and there is to be added solution of acetate of lead; a white flocculent precipitate forms of sebate of lead, which is to be collected and dried, put into a phial, and have added to it an equal weight of sulphuric acid diluted with 5 or 6 times its weight of water, the whole is then heated to 212° . A decomposition takes place, the whole is to be filtered and crystals of sebacic acid will separate as the liquid cools. These are to be collected and washed with cold water until the liquid ceases to precipitate nitrate of barytes.

Sebacic acid is a solid, which crystallizes in small white needles of little firmness, which is destitute of odour, has a faint taste, reddens delicate vegetable blues, and has a density greater than that of water.

Exposed to heat it melts like fat, is decomposed and in part volatilized.

It is very soluble in hot water, and in alcohol. It combines with the alkalies and forms soluble salts, and when their solutions are decomposed by nitric or muriatic acid, sebacic acid precipitates.

Sebacic acid precipitates solutions of nitrate and acetate of lead, acetate and nitrate of mercury, and nitrate of silver.

According to Thenard its constituents are oxygen, carbon, and hydrogen, the latter being in excess in relation to the oxygen.*

* *Traité de Chimie*, t. iii. p. 498. 2d. edit.

CHAP. II.

OF THE FLUIDS AND SOLIDS OF THE ANIMAL BODY.

In the preceding chapter have been detailed the properties of the component parts of animals, which answer to the proximate principles of vegetables. We shall now describe the different fluids and solids which consist of or contain these proximate elements.

SECTION I.

Of the Blood.

DCCCXCIX. No portion of the body presents more interesting properties nor has been more extensively and minutely examined than the blood. While the physiologist has been employed in investigating its modes of formation, the phenomena which it displays, the uses to which it is destined, and the changes which it undergoes in the living system, the attention of the chemist has been occupied in tracing the changes to which it is exposed when withdrawn from the body, and in discovering the substances of which it is composed. Of all animal products this fluid has been examined with the greatest care, and by the most distinguished philosophers, and yet, such have been the peculiar difficulties attending its analysis, that we cannot even now be considered as having acquired a full and satisfactory knowledge of its nature and composition.

DCCCC. Blood is formed by the vital processes to which organic substances are exposed in the living systems of animals. For example, in man the food, either animal or vegetable, or a mixture of both, after having been comminuted by the teeth and mixed with saliva, is carried into the stomach, where it is subjected to the process of digestion. By this operation it is converted into a grayish pultaceous mass, which has been designated by the name of *Chyme*. The ac-

tive agent in this change appears to be a substance called the gastric liquid, which possesses strong solvent powers, and is known to act even after death, upon the coats of the stomach, and to dissolve them and perforate that organ. Chyme is modified, at least in its physical characters, by the nature of the food. According to the experiments of Dr. Marcet, it is neither acid nor alkaline; it contains albumen, and several neutral salts. When evaporated to dryness, it left $\frac{1}{8}$ of its weight of solid matter, and on maceration the residue was 12 parts to 1000 employed. The chyme employed was that of a turkey.*

DCCCCI. On leaving the stomach this mass becomes mixed with the bile, pancreatic juice, and the fluids secreted by the glands, suffers modifications in texture and composition, is converted into *Chyle*, and during its passage through the alimentary canal, is absorbed by the lacteals, conveyed through the mesenteric glands to the receptacle of the chyle, thence passes into the thoracic duct, and is poured into the circulating fluids, through the left sub-clavian vein.

DCCCCII. Chyle presents some interesting properties, and has lately been examined with some attention by different chemists, particularly M. Vauquelin, Mr. Brande, and Dr. Marcet. The chyle of such domestic animals as have been examined, is a colourless and nearly transparent, inodorous liquid, of a sweetish taste, and capable of restoring the blue colour of litmus which has been reddened by acetic acid; hence it contains an uncombined alkali. When withdrawn from the body, it coagulates in the course of 12 minutes, and on being allowed to stand undisturbed for 24 hours, separates into two portions, the one fluid, the other solid and of considerable firmness. According to Dr. Marcet, it contains albumen, and by Vauquelin it is considered as a substance intermediate between albumen and fibrin. It is soluble in the alkalies, but insoluble in alcohol. The nitric acid

* Annals of Philosophy, vol. vii. p. 235.

decomposes and is decomposed by it. Its ashes afford common salt, phosphate of lime, and traces of iron. The liquid part of the chyle is of a specific gravity of 1.02; it does not readily putrefy; it is coagulated by the same substances which effect this change in albumen. When evaporated, it leaves about 4.8 per cent of a yellow, deliquescent residuum. Mr. Brande, by evaporating the liquid after the coagulated albumen had been separated, obtained a crystallized substance which exhibited the properties of sugar of milk.

After the chyle is mingled with the blood, it probably requires repeatedly to run the course of the circulation before it is converted into a sanguineous fluid; for if a vein be opened after a full meal, the chyle may be observed in the blood discharged from the wound.

DCCCCIII. Perfectly healthy blood when drawn from a vein is of a dark crimson, from an artery of a bright florid, or scarlet colour; it is opaque, soft to the feel, and adhesive, of a faint odour, and a sweetish, saline taste. Its specific gravity is about 1.052. In the course of from 12 to 15 minutes after its abstraction from the body, a thin film appears at the edges, which gradually extends over the surface, and penetrates into the substance of the mass; it loses its fluidity, and is finally converted into a solid of some firmness. This spontaneous process is called the *coagulation of the blood*, and no satisfactory reason has yet been assigned for this change, unless it be considered with Mr. John Hunter as an evidence of the vitality of the blood. Soon after its coagulation, another spontaneous process commences which goes on for several hours, and which terminates in the natural analysis of the mass into two distinct substances. A liquid is observed to ooze from the surfaces of the coagulum, the solid mass diminishes in size and increases in firmness, and when the process is concluded it will be seen floating in a liquid of a yellow colour. This liquid has received the name of *Serum*, and the solid that of *Clot* or *Crassamentum*. The proportion of one to the other cannot be accurately ascertained, because it

varies according to circumstances ; in general it is in the ratio of about 2 of crassamentum to 3 of serum.

Serum.

DCCCCIV. Serum is a liquid of a straw-yellow colour, transparent, of an oily, viscid feel, of a slightly saline taste, and of a specific gravity of about 1.023. It converts vegetable blues to a green, and therefore contains an uncombined alkali, which was proved by Rouelle to be soda. or its sub-carbonate. On exposure to heat it begins to experience coagulation at the temperature of 165°, and is finally converted into a yellowish white solid of some firmness and consistency. The same effect is produced by a small quantity of boiling water, by the acids, and the salts which have an excess of acid. When coagulated by heat, it has much the appearance of the white of an egg which has been rendered solid. In fact, it has been sufficiently demonstrated, that the principle on which the coagulation depends is the same in both, and it may therefore be shown by these simple experiments that the principal portion of serum, abstracting its water, is *albumen*.

DCCCCV. When coagulated serum is pressed, there oozes from its surface a small quantity of liquid, which has been named by physiologists the Serosity, and which was for some time supposed by chemists to contain or consist of gelatine. The researches however of Dr. Bostock have led to the conclusion that this is not the case, for by his experiments it would appear to be composed of a small portion of albumen, and of a principle analogous to mucus.* Berzelius likewise affirms that gelatine does not exist in the blood.†

DCCCCVI. Besides sub-carbonate of soda, the serum has been found to contain muriate of soda, muraite of potash, and lactate of soda.

* Nicholson's Journal, vol. xxxii. p. 47.

† Medico-Chirurgical Transactions, vol. iii. p. 178.

The analysis of the serum has been executed with precision both by Berzelius and Dr. Marcet. The results obtained by the former were

Water	-	-	-	-	-	-	-	905.00
Albumen	-	-	-	-	-	-	-	80.00
Substances soluble in alcohol, viz. muriate of potash and soda	-	-	-	-	-	-	6	10.00
Lactate of soda, united with animal matter	-	-	-	-	-	-	4	
Substances soluble only in water, viz. soda, phosphate of soda, and a little animal matter	-	-	-	-	-	-	4.1	4.10
								999.10*

Dr. Marcet's analysis gives as the contents of serum

Water	-	-	-	-	-	-	-	900.0
Albumen	-	-	-	-	-	-	-	86.8
Muriates of potash and soda	-	-	-	-	-	-	-	6.6
Muco-extractive matter	-	-	-	-	-	-	-	4
Sub-carbonate of soda	-	-	-	-	-	-	-	1.65
Sulphate of potash	-	-	-	-	-	-	-	0.35
Earthy phosphates	-	-	-	-	-	-	-	0.60
								1000.00

Crassamentum.

DCCCCVII. From the spontaneous decomposition of the blood, and the separation of the serum, it is obvious that all the parts of this fluid are not coloured, but that the colouring matter remains in connexion with the solid cruor or crassamentum. By a simple process it may likewise be demonstrated that this solid consists of at least two distinct substances, one of which is coloured, while the other is white. If a portion of the crassamentum be gently washed in repeated quantities of cold water, the liquid will assume a red colour,

* Medico-Chirurgical Transactions, vol. iii.

while that of the solid will become proportionally diluted, and when the mass is allowed to rest in a fresh portion of water, its edges will appear to be fringed with a white, translucent, and delicate membrane. The same effect may be more completely obtained by tying the crassamentum in linen, and washing it for a long time in large and successive portions of cold water. In this way the colouring matter will be removed from some parts of the mass, and the substance which remains will be found to exhibit a fibrous structure, tough and elastic. In fact it has all the properties of *Fibrin*, one of the principles of animal bodies which we have already described. It has likewise been shown to contain albumen both by Mr. Brande and Professor Berzelius, and the latter states the crassamentum to consist of 64 parts of colouring matter, and 34 of fibrin and albumen.

DCCCCVIII. The properties of the crassamentum as a whole are as follows. It is a firm, but tremulous solid of a dark red colour, which assumes a florid red on exposure to the air, or to oxygen gas, and by the action of some of the neutro-saline compounds, such as nitrate or chlorate of potash. This change in colour takes place only at the surface, and it is accompanied with the absorption or at least the disappearance of oxygen. On exposure to the gases which contain no oxygen, the dark colour either remains the same or becomes more intense. Crassamentum may be exposed for some days to the air, provided the serum be removed, before it putrefies. It becomes dry and hard at the surface, and the crust thus formed probably prevents the access of the air. When subjected to destructive distillation, it yields the usual products, and its ashes afford carbonates and phosphates of lime and the alkalies, together with oxide of iron.

Colouring matter.

DCCCCIX. Of all the constituent parts of the blood none presents more curious properties, nor offers a better subject

for experiment and philosophical speculation, than the substance from the presence of which is derived its colour. It is commonly known by the name of *Red globules*. It was ascertained many years ago by Lewenhoeck, that by the aid of a lens of great power, the blood, as it was circulated in the vessels of animals, exhibited minute spheres or globules floating in a transparent liquid, and Mr. John Hunter affirms, that they may be seen taking a direct, lateral, or retrograde course, according to obstructions existing in the vessels themselves, or operating externally. The form and structure of these globules attracted the attention of physiologists, but from their minuteness, nothing very definite respecting them has been discovered. Lewenhoeck supposed that each globule was formed of six smaller globules, that each of these was likewise composed of six others still more minute, and that though when united they produced colour, yet that in their separate state they were colourless. By the Abbé Torri they were concluded to be rings; and Dr. Falconer supposed each of them to consist of a nucleus, surrounded by a flattened ring. These globules, it is said, may be conveniently seen by diffusing a little of the colouring matter of blood in serum, in which they will swim without being dissolved. One of these globules has been calculated to be equal in diameter to $\frac{1}{2000}$ part of an inch. Dr. Young affirms that the globules are colourless, but surrounded by a red matter, and the size of one of them varies from $\frac{1}{4000}$ to $\frac{1}{8000}$ of an inch in diameter.

DCCCCX. From the period of the experiments of Fourcroy and Vauquelin, until Mr. Brande undertook to examine its composition, the substance which gives the blood its colour, and which is considered as its most important constituent, was supposed to be iron in union though not saturated with phosphoric acid. But the results of Mr. Brande's researches, which have been confirmed by those of Professor Berzelius and of M. Vauquelin, have sufficiently demonstrated, that this matter, instead of being metallic, is of an animal nature;

and by certain processes may be obtained in a separate state.

DCCCCXI. Mr. Brande obtained this matter by agitating blood as it flowed from a vein with a stick, to which the fibrin was made to adhere, and was thus removed. The remaining fluid, when allowed to stand at rest for some time, deposited a coloured substance, from which the clear serum was decanted. Thus procured, it still contained albumen, and was not quite pure.

The process of Berzelius consisted in cutting crassamentum into thin slices, placing them between folds of bibulous paper to absorb the serum, and afterwards tritulating them in water. An opake and deep coloured solution was thus obtained, which when heated nearly to ebullition caused a coagulation and separation of a brown opake mass, which was easily collected and dried.

M. Vauquelin separated the colouring matter from the other principles of the blood by the following method. Crassamentum freed from serum was put upon a seirce and well mixed with four parts of sulphuric acid previously diluted with eight of water. The mixture was heated and kept at the temperature of 158° for six hours, then filtered, and the residue was washed with water equal in weight to the acid employed. After being evaporated to half its bulk, ammonia was added until the acid was nearly saturated, and the precipitate, which consisted of the colouring matter, was washed with water until it was incapable of precipitating nitrate of barytes. It was then thrown upon a filtre, and after the liquid had drained off, was removed by an ivory spatula and dried in a capsule.

DCCCCXII. The substance thus obtained when dry is black and destitute of taste and smell. It is soluble in cold water and communicates to it a wine-red colour. The solution, when heated nearly to ebullition, becomes cloudy and opake, and a coagulum, consisting of the colouring matter, is separated. According to Berzelius, alcohol and ether convert

it into a fatty substance similar in properties to adipocire. It is soluble in the acids; with acetic acid it forms a soft jelly, soluble in tepid water, decomposable by the alkalies and alkaline prussiates, and depositing a substance which consists of the colouring matter unaltered. The prussic acid, therefore, says Berzelius, appears to exert no action upon the colouring matter of the blood. The solutions of this matter in acids appear by reflected light of a deep cherry red colour, by transmitted light of a greenish colour. Berzelius could not effect a solution of it in muriatic acid.

It is likewise dissolved with facility by the alkalies.

When dissolved by nitric acid, it is not affected by muriate of barytes, gallic acid, nor the prussiates; it is precipitated by infusion of galls, but without changing its colour.

Some curious experiments were made by Mr. Brande for the purpose of ascertaining whether it were capable of uniting with bases to form lakes, and with fibrous substances to constitute a dye. As the results, he found that it was precipitated by some of the mercurial salts, such as the nitrate and corrosive muriate, and that it formed lakes of a red colour, permanent in the air.

DCCCCXIII. According to Vauquelin, when this principle is distilled, it yields little or no gas, neither does it change its form or colour, but exhales an odour similar to that of other animal substances, produces carbonate of ammonia, and an oil of a reddish purple colour. The coal which it leaves is bulky and is reduced to ashes with great difficulty. These ashes are yellow. It is thought by Berzelius, that the carbonaceous matter, which remains after the flame has ceased, is not simply a mechanical mixture of charcoal with the phosphates and carbonates of the earths and of iron. "We must consider it as a chemical combination of carbon, phosphorus, and sulphur, with calcium, ammonium, and iron; and it appears that it is in a mode analogous to this combination, that the iron, as well as the calcium, phosphorus, &c. are united with the charcoal, and other constituents of the colouring matter."

And he subjoins the following important observation. "For it is sufficiently obvious that the mode in which combustible bodies combine with one another, and with a small portion of oxygen in organic substances, is totally different from that which prevails among the inorganic productions of nature."

Berzelius analyzed the ashes obtained by the incineration of 400 grains of colouring matter. They amounted to 5 grains, and the results were as follows :

Oxide of iron - - - - -	50.00
Sub-phosphate of iron - - - - -	7.50
Phosphate of lime, with a small quantity of magnesia } -	6.00
Pure lime - - - - -	20.00
Carbonic acid, and loss - - - - -	16.50
	<hr/> 100.00

DCCCCXIV. From what has been said of the properties of the colouring matter of the blood, it will appear evident, that it is to be considered as a peculiar animal substance, very analogous in its properties to fibrin. It is remarked by Berzelius, "that the colouring matter has the same chemical properties, and consequently the same chemical composition, as the fibrin; but these two bodies are distinguished from each other principally by a difference in colour; by the fibrin coagulating in all temperatures, while the colouring matter may be dried without losing its solubility in water, and becomes insoluble only at a certain temperature; and lastly by the peculiar character of the latter when coagulated, such as its not being diminished in volume while drying, as happens with fibrin."

Respiration.

DCCCCXV. Of all the animal functions, that of respiration has attracted most attention from the chemists, and the reason is, that the agents employed in the process are well

known, and the changes which take place are more open to investigation than those which result from the exercise of other living operations. A vast number of chemists and philosophers have been successively engaged in these researches, but the limits of this work will not admit of much detail, and we shall, though with reluctance, confine ourselves to the general facts which have been collected in relation to this interesting part of physiology.

DCCCCXVI. 1. It is generally known that the heart is a double organ, and that the blood which is thrown from the left ventricle is destined for the supply of the system, and to afford the materials for the different secretions, while that which passes from the right ventricle, after running a limited course through the lungs, returns to the left side of the heart, whence it is propelled into the great artery of the body, and its minute ramifications. On leaving the arteries this sanguineous fluid enters an intermediate system of vessels, called the *capillaries*, which are probably the agents in the different secretory processes, and from them it passes into the veins. While circulating in the arteries, the blood is of a bright scarlet colour, but during its passage through the extreme vessels, and its ingress into the veins, it changes to a purplish red colour; which apparently increases in intensity as it approaches the heart, until it is emptied into the right auricle and ventricle. From the last it is propelled into the pulmonary artery, by which it is carried to the lungs, and there while circulating in its minute vessels its colour is again changed to a scarlet, and in that state conveyed to the heart. The lungs are composed of air-cells, formed by a membranous substance, between the coats of which the small branches of the pulmonary artery are probably arranged.

DCCCCXVII. 2. The same portion of air cannot be breathed for any length of time with impunity; to support life, the fact is familiar that fresh air is absolutely necessary. If the air which is expired be examined, it will be found to have undergone essential changes, and these changes consist, first,

in the disappearance of a portion of oxygen; and secondly, in the production of an equal bulk of carbonic acid. Hence the changes which take place during respiration, relate, both to the circulating blood, and the atmospheric air inhaled.

DCCCCXVIII. 3. It has been found a difficult point to ascertain the extent of the change which happens to the inspired air, or in other words the quantity of oxygen consumed and that of carbonic acid evolved in a given time, because this must depend upon the whole quantity of air inspired, and that which remains after expiration; now these must be influenced by various causes, particularly the capacity of the pulmonary organs, the power of the respiratory muscles, the temperature, and the mode in which the process is conducted. Upon an average it is supposed that the lungs of a man contain in their ordinary state 280 cubic inches of air, and that 40 cubic inches are inspired and expired during one respiration, which, if the number of respirations in a minute be estimated at 20, will make the whole air taken in and thrown out of the lungs in an hour equal to 48000 cubic inches. The quantity of oxygen which disappears in a minute has been variously stated at from 26.6 to 38 cubic inches. Messrs. Allen and Pepys found that when respiration was somewhat hurried, the carbonic acid expelled amounted to 32 cubic inches in a minute, but when performed moderately it was only 26.6 cubic inches. Now it seems to have been sufficiently proved by these gentlemen, that the carbonic acid thrown out of the lungs is precisely equal to the oxygen of the air which had been taken in and which had disappeared. Hence the quantity of oxygen consumed in a minute in respiration lies between 26.6 and 32 cubic inches; the mean is 29.3 cubic inches, which gives 1758 cubic inches in an hour, and 42292 cubic inches in a day, of oxygen consumed and of carbonic acid evolved. Hence if this gas consist in round numbers of 72 of oxygen and 28 of carbon, and 100 cubic inches weigh 47 grains, the amount of solid carbon, in combination with oxygen, discharged in 24 hours from the

lungs, will be more than *ten ounces*, a quantity which equals probably, if it do not exceed that of the carbon taken into the system in that time ; and which might lead to the belief that the carbonic acid evolved has been over-rated.

DCCCCXIX. 4. When air is expelled from the lungs, it is always saturated with aqueous vapour, which is probably transpired through the delicate membrane that lines the pulmonary vesicles. This water has been estimated at about 3 grains in a minute, or 9 ounces troy in 24 hours.

DCCCCXX. 5. The experiments of Sir. H. Davy and Dr. Henderson appeared to prove that azote likewise disappeared during respiration, in which opinion they coincided with the earlier experiments of Priestley and Lavoisier. The later researches however of Allen and Pepys have shown that this is not the case, and M. Berthollet has even inferred a disengagement of this principle. We may therefore conclude that in respiration as in combustion, the azote of atmospheric air is passive. Mr. Ellis found that azote was not consumed by the lower classes of animals ; but according to the experiments of Humboldt and Provençal, a portion both of oxygen and azote is absorbed into the systems of fishes during their respiration.

DCCCCXXI. Such then are the changes which take place in atmospheric air in consequence of being breathed. How are these changes effected, and what are the agents ? To answer these questions, it will be necessary to ascertain the modifications to which the blood is subjected in the lungs. These are, 1. a change of colour from dark purple to scarlet. 2. An apparent increase of fluidity. 3. The disengagement of water. 4. The discharge of carbon. It will not be necessary to state the different hypotheses to account for these changes, because they would carry us too far into detail, and because in fact these hypotheses are exploded. They were founded upon the supposition that oxygen was actually absorbed, or that hydrogen and carbon in combination, were discharged from the pulmonary system.

Venous blood, when exposed to the air, or to airs which contain oxygen loosely combined, acquires at the surface a florid colour, similar to that which it assumes in the lungs. The same effect has been found to take place through a moistened bladder and other animal membranes. This fact has been adduced to prove the absorption of oxygen by the blood ; but this conclusion does not necessarily follow ; it may merely demonstrate that the membranes do not prevent the combination of the carbon of the blood with atmospheric oxygen. When blood in fact is thus exposed, oxygen is consumed and carbonic acid formed. It has been proved by Count Rumford and Sir. H. Davy, that carbon will unite with oxygen at temperatures far below ignition. In respiration this element is in a very favourable state for such a combination ; it is probably secreted, perhaps transpired, in a very attenuated state and at a considerable temperature, in which form its attraction for oxygen will be more effective, and thus produce carbonic acid. The change therefore from venous to arterial blood may be supposed to depend solely upon the discharge of carbon, and the following be considered as approximating, as nearly as facts will permit, to a correct view of the reciprocal influence of the blood and of atmospheric air, and the use of respiration.

DCCCCXXII. The separation of nutritive matter and the secretory processes take place in the capillary system ; the blood until it enters this system is arterial, but when here it affords the elements of animal matter, which consist of carbon, hydrogen, oxygen, and nitrogen or azote, of which the last is in greatest, and the two first in least proportion. While therefore most of the nitrogen will be appropriated and animalized, the largest portion of carbon will be rejected, or become excrementitious ; the blood, with this redundant quantity of carbon, will enter the veins, be carried to the right side of the heart, whence it will be urged into the pulmonary artery and its minute ramifications in the lungs ; here it will part with its excess of carbon, and be thus recon-

verted into arterial blood destined to supply the waste or contribute to the growth of the whole animal system. There is no evidence of any other change experienced by the blood in the lungs than the loss of a portion of its carbon, if we except the water transpired. There is no proof that oxygen is absorbed by it, and none of the hypotheses which have been founded upon this supposed fact can be supported. They are encumbered with difficulties which cannot be surmounted.

DCCCCXXIII. We must now advert to another very important phænomenon which has been inferred to depend upon respiration, and that is *Animal Heat*. It is well known that the temperature of the human system is constantly the same, to whatever changes it be subjected; that in all climates it varies but little, and that there must be some cause operating constantly and uniformly to produce this equilibrium.

We owe to Dr. Crawford one of the most beautiful of theories to account for the uniformity and constancy of animal heat. According to this philosopher, the capacity of venous compared with that of arterial blood for heat is as 10 to $11\frac{1}{2}$, consequently in the conversion of the former into the latter, the capacity is increased, and if the caloric were not immediately supplied, the temperature would sink 200° ; but a provision has been made for this purpose in the difference of capacity between oxygen and carbonic acid. From the data which he assumes the capacity of oxygen gas is 4.749, and that of charcoal 0.2631; when combined in the form of carbonic acid the capacity of the compound is equal to 1.0454; hence, supposing the difference to amount to 3, and that the absolute heat of oxygen gas is 1551° , the oxygen during its conversion into carbonic acid in the process of respiration, must give out a quantity of heat equal to 1451×3 , or 4653° ; now the temperature of ignition being about 1050° , a degree of heat three times greater than red hot iron above the temperature of the air, must be evolved. What becomes of all this caloric? Crawford endeavours to show

that part is absorbed by the blood as it passes from venous to arterial, and part by the aqueous vapour which he supposes to be formed by the union of another portion of oxygen with hydrogen given out by the lungs. As the blood in its circulation comes to the capillaries, its capacity, while changing to venous, is gradually diminished, and it evolves a quantity of caloric proportional to the difference of capacity of the blood in its two states. Thus the temperature of parts remote from the lungs is preserved.*

DCCCCXXIV. It is to be lamented that a theory so ingenious, founded apparently upon such rigid demonstration, and so adequate to explain the production and continuance of animal heat, should be doomed to fall. Yet this will probably be its fate, as well as of all those likewise which attempt to explain the functions of animals upon pure chemical principles.

The objections to Crawford's theory are founded upon the experiments of Dr. John Davy, Berzelius, M. M. Berard and Delaroche, and Mr. Brodie. According to the results of Dr. Davy's researches, arterial blood has a *less* capacity for caloric than venous; and Berzelius could find no difference between them. The French philosophers have shown that the difference between the capacities of oxygen gas and carbonic acid is only 0.0568 instead of 3.0000, so that on the data of Crawford the heat given out in the lungs, instead of being above 4000°, should amount only to 103°. The experiments of Mr. Brodie are supposed to go still farther, and to prove that animal heat is not in any degree dependent upon respiration. Yet as the experiments were performed on animals in extraordinary circumstances, it may be doubtful how far the results might have been influenced by causes foreign to those assigned. In morbid states of the system it will sometimes be found that the temperature at the surface depends upon circumstances apparently independent both of the

* Experiments and Observations on Animal Heat. 2d. Edit.

quickness of respiration and the frequency of the pulse, and the partial and occasional production of heat may with more propriety be referred to the influence of the nervous system.

In the present state of our knowledge it is impossible to give a satisfactory reason for the constant evolution of heat in the living system, and so far as this admission goes, it is in favour of the opinion that it depends rather upon a vital than a chemical process.

SECTION II.

Of Milk.

DCCCCXXV. Milk is a fluid secreted by the females of mammiferous animals, and is the provision made by the Author of nature for the nourishment of their offspring. Its general properties are the same, from whatever animal it is obtained. The succeeding observations will apply principally to that of the cow.

DCCCCXXVI. Milk is a white opake liquid, of a bland sweetish taste, of a faint but peculiar odour, and of a specific gravity rather greater than that of water. It changes vegetable blues to a red. On exposure to variations of temperature, it boils and freezes at nearly the same degrees as water. On being allowed to remain at rest for some hours, it undergoes a species of spontaneous decomposition; its surface becomes covered with a thick white oily substance, and the fluid beneath is thinner and of a bluish colour.

Cream.

DCCCCXXVII. Cream, the substance which rises to the surface of milk on standing, is a thick, white, and bland liquid, of an agreeable somewhat oily taste and feel. It is lighter than water. On exposure to the air for a few days, it increases in thickness, acquires a strong, peculiar flavour, and at length becomes rancid. If boiled for some time, a

small quantity of oil rises to the surface. Cream in fact is of an oily nature ; it leaves a greasy stain upon clothes, and when agitated for some time, it produces this oil in a concrete state. Cream is insoluble in alcohol or oils. It is composed of the oil above mentioned, a caseous matter, and whey or serum. When it is put into a churn and agitated for some time, a separation of these constituents takes place, and a solid, which is familiar by the name of *butter*, and a liquid called butter-milk, consisting of the whey and the caseous part, are the products.

DCCCCXXVIII. Butter is white with a shade of yellow, of a soft consistence, and has properties analogous to oils. It is insoluble in water and alcohol, but soluble in oils, and mixes readily with fatty bodies. On exposure to heat, it melts at the temperature of 96° , and assumes the appearance of oil. At the same time it deposits a small portion of caseous matter and whey. Butter, as usually prepared, always contains more or less of these substances, from which it acquires its tendency to become rancid. The purer it is obtained, or in other words, the more perfectly the butter-milk is separated, the longer may it be preserved. It is said that if, after it has been melted, it be poured off from the sediment and when cold be put into close vessels, it may be kept without change for many months. But this process, it is affirmed by some, deprives the butter of a great part of its flavour. The melting, when practised, should be conducted at the lowest possible heat. Butter is never completely separated from milk, and it is found not only in creamed milk, but likewise in whey ; for it has been ascertained by actual experiment, that butter may be obtained by churning whey. Twenty seven Scotch pints of whey yield at an average about one pound of butter. This accounts for a fact well known to those who superintend dairies, that a good deal more butter may be obtained from the same quantity of milk, provided it

be churned as it comes from the cow, than when the cream alone is collected and churned.*

DCCCCXXIX. With regard to the proportions of the three constituents of cream, they were found by Berzelius to be of

Butter	-	-	-	-	-	-	4.5
Cheese	-	-	-	-	-	-	3.5
Whey	-	-	-	-	-	-	92.0
							<hr/>
							100.0

Butter according to Chevreul is composed of stearine, elaine, a small quantity of acid, and colouring matter.

Its ultimate elements, from the experiments of Berard, are

Carbon	-	-	-	-	-	-	66.34
Oxygen	-	-	-	-	-	-	14.02
Hydrogen	-	-	-	-	-	-	19.64
							<hr/>
							100.00

The acid in this compound is said by Chevreul to be of a peculiar nature, and to form very characteristic salts with the salifiable bases. He has called it *butiric acid*.

Cheese, or Caseous Matter.

DCCCCXXX. If skimmed milk, or the liquid after the separation of the cream be left to itself for some time, it grows sour, and a coagulation taking place, a solid substance separates, which, when collected and pressed, constitutes caseous matter, or cheese. This coagulation may be produced artificially at any period by the use of acids, or some of the neutral salts, or alcohol. Hence in the formation of cheese it is customary to *turn* the milk with rennet, which is the

* Thomson's Chemistry, vol. iv. 506. 5th edit.

stomach of a calf deprived of its outer membrane. The liquid found in this organ produces the same effect, and it is remarkable that this coagulating power is independent of the presence of an acid, as has been sufficiently demonstrated by the experiments of Parmentier and Deyeux, and of Dr. Young.

DCCCCXXI. Caseous matter is a white or grayish white solid, nearly insipid to the taste when fresh, but grows acrid by time, and somewhat elastic, and if dry, brittle. On exposure to the air in its usual state, it goes through the putrefactive process, but when deprived of its moisture it is little altered. It is insoluble in its simple state in water, but may be dissolved in that liquid, by previously precipitating it from milk by an acid, and digesting the coagulum with carbonate of lime or barytes, which abstracts the acid and renders the cheese soluble. Cheese is likewise soluble in the alkalies; the odour of ammonia is at the same time exhaled, and if an acid be added, a dark red precipitate is formed, the odour of sulphuretted hydrogen is disengaged, and the liquid has the property of blackening silver, sufficient proofs that one of the constituents of cheese is sulphur. It is dissolved readily by acetic acid, but decomposed by nitric acid. With the mineral acids it forms compounds, similar to those of albumen and fibrin.

DCCCCXXII. Caseous matter when distilled produces empyreumatic oil, ammonia and carburetted hydrogen gas. Whence it is evident that it is to be considered as a quaternary compound, and the proportions of its ultimate elements, according to Gay-Lussac and Thenard, are

Carbon	-	-	-	-	-	-	59.781
Oxygen	-	-	-	-	-	-	11.409
Hydrogen	-	-	-	-	-	-	7.429
Azote	-	-	-	-	-	-	21.381*
							<hr/>
							100.000

* *Rechères*, t. ii. p. 334.

When incinerated, it yields phosphate of lime. Hence it is to be considered as one of the proximate elements of milk the best adapted to the nourishment of the young, as remarked by Berzelius; for it bears a great resemblance in its properties to albumen and fibrin, which constitute the greater part of the softer animal solids, and the earthy phosphates which it contains no doubt go towards the increase of the bones.

Cheese formed from caseous matter alone is dry, insipid, or disagreeable to the taste. Its estimable properties depend upon the quantity of cream or rather of its oil with which it is associated.

Whey or Serum.

DCCCCXXXIII. After the separation of cream and caseous matter from milk, there remains a liquid called *whey*. It may be prepared readily by adding to about a quart of milk nearly boiling hot, a spoonful of vinegar, filtering or straining the liquid, clarifying it with the white of an egg beat up with 7 or 8 parts of water, and again straining. It is a liquid of yellowish colour, limpid, and of an agreeable though faint taste. When evaporated to a certain degree, it deposits a crystalline substance, which, if redissolved in water and crystallized, constitutes *sugar of milk*. It likewise yields muriates of potash and soda, and phosphate of lime.

DCCCCXXXIV. Sugar of milk crystallizes in regular parallelopipeds or in rhomboidal tables, white, of a sweetish taste, but inodorous. It is soluble in water, requiring 5 parts of cold, and $2\frac{1}{2}$ of boiling water, for its solution. It is insoluble in alcohol and ether, but by the addition of a small quantity of sulphuric acid, it is rendered soluble in the first of these liquids. It is dissolved by acetic and muriatic acids, and absorbs muriatic acid gas, forming with it a gray powder. It is decomposed by chlorine, and strong solution of potash. By nitric acid it is converted into sac-

lactic acid. Bucholz affirms that it is incapable of going through the vinous fermentation.

On exposure to heat, sugar of milk melts, is then decomposed, and affords a residue of charcoal. According to Gay-Lussac and Thenard it consists of 38.825 of carbon, 53.834 of oxygen, and 7.341 of hydrogen. Berzelius states the proportions at 45.267 of carbon, 48.348 of oxygen, and 6.385 of hydrogen.

Whey in its recent state reddens litmus, and the acid which produces this effect, is the lactic. When allowed to rest for some time it becomes sour to the taste, and it is known to depend upon the presence of acetic acid, which forms in consequence of the sugar of milk, and its other ingredients having undergone the acetous fermentation. Whey also contains, according to Fourcroy and Vauquelin, phosphates of magnesia and iron.

DCCCCXXXV. Such are the properties of the constituents of milk. With regard to their proportions, they are stated by Berzelius as follows, the analysis having been made of this fluid, after the separation of the cream.

Water	-	-	-	-	-	-	928.75
Cheese, with a trace of butter	-	-	-	-	-	-	28.00
Sugar of milk	-	-	-	-	-	-	35.00
Muriate of potash	-	-	-	-	-	-	1.70
Phosphate of potash	-	-	-	-	-	-	0.25
Lactic acid, acetate of potash, with a trace of lactate of iron	}						6.00
Earthy phosphates	-	-	-	-	-	-	0.30*
							<hr/> 1000.00

DCCCCXXXVI. It is affirmed by Proust, that the taste and odour of cheese depend upon the presence of two substances which possess characteristic properties, and are

* Medico-Chirurgical Transactions.

named by him Caseous oxide, and Caseic acid. They may be obtained either from cheese or gluten. When fermented gluten is covered with water in a close vessel and allowed to remain at rest, a series of changes ensues by which acetate, phosphate, and caseate of ammonia are formed. If the fluid be poured off and evaporated to the consistence of syrup in a silver basin, acetate and carbonate of ammonia are deposited, and the syrup on cooling becomes a concrete saline mass. On agitating the mass with alcohol, part dissolves, while part is deposited in the form of a white powder, which when dissolved in hot water, and obtained by cooling, constitutes *caseous oxide*. It is a light, white, spongy mass, like agaric, soft, crumbles under the fingers and leaves a greasy feel. It has none of the odour of cheese. It is incapable of crystallizing, begins to dissolve in water at 140° , is combustible and burns with a white flame. It is slightly soluble in alcohol and separates as the solution cools in crystalline grains. Its aqueous solution is not affected by acids or alkalies, but the solid oxide is soluble in potash. Nitric acid converts it into oxalic acid and bitter principle. On exposure to heat, part volatilizes and the other part is decomposed, yielding abundance of yellow oil which congeals, a little water, and less ammonia.

DCCCCXXXVII. *Caseic acid*. The alcohol, with which the saline mass above mentioned is washed, contains this acid in combination, more alcohol is added, and after a while a portion of gum subsides, the liquid is then distilled, and the saline mass obtained, consisting of carbonate, phosphate, acetate, and caseate of ammonia, is dissolved in water and boiled with carbonate of lead; by these means the ammonia is dissipated, and when filtered, phosphate of lead is separated; a stream of sulphuretted hydrogen being passed through the liquid precipitates the remaining lead, acetic and caseic acids are disengaged, and the former is removed by distillation. Caseic acid is a liquid of the consistence of syrup, of an acid, bitter, and cheesy taste. It reddens litmus. It

precipitates nitrate of silver, white; muriate of gold, yellow; and corrosive sublimate, white. With infusion of galls it deposits a thick white matter. It is unaltered by chlorine, but by nitric acid is converted into oxalic and benzoic acids. It combines with bases. Caseate of ammonia has an excess of acid, a sharp, bitter and peculiar taste, is uncrystallizable, and is decomposable by potash.

Both of these substances are produced abundantly by curd, and Proust affirms that caseate of ammonia is the sapid and odorous principle of cheese. Caseous oxide occurs frequently in cheese in detached points and solid, which affect the teeth like earthy and dry substances. A cheese from Villalare afforded him $\frac{2.8}{100}$ of acid, oxide, and a little gum; from Gruyere $\frac{3.4}{100}$; from Roquefort $\frac{3.0}{100}$; and from Oviedo $\frac{3.6}{100}$.*

DCCCCXXXVIII. Though the general properties of milk are the same in different animals, yet they differ from each other in the relative proportion of their constituent parts.

Human milk differs from cow's milk in being sweeter to the taste, and consequently in containing a larger proportion of sugar, the proportion according to Haller being as 58 to 35, or sometimes as 67 to 37. The cream likewise is white and in larger proportion; but what is remarkable, this cream is incapable of yielding butter by any process hitherto discovered. If it be allowed to rest for some time after having been agitated, it separates into two portions, both fluid, but one almost as thin and colourless as water, while the other is thick, white, and oily.

Of all animals the milk of the ass approaches nearest to that of the human species. Goat's milk is very similar to that of the cow. The milk of the mare is thinner than that of the cow; it yields no butter, and differs from other milk in being susceptible of going through the vinous fermentation, and of forming a weak intoxicating liquid. It is well known that a drink of this kind is prepared by the Tartars.

* Journal of Science and the Arts, vii. 389.

SECTION II.

Of Bile.

DCCCCXXXIX. The bile, which is secreted from venous blood, while the other fluids are formed from arterial, is, in the human subject, a liquid of a brownish yellow colour, though occasionally greenish, or with a faint shade of colour, of a bitterish taste, but destitute of odour. It is not apparently homogeneous, but holds in suspension some matter of a yellowish colour, which renders the bile grumous. When filtered and evaporated, it affords a brown residue equal in weight to $\frac{1}{11}$ of the liquid; and this substance, on being incinerated, yields soda, muriate, sulphate, and phosphate of soda, phosphate of lime, and oxide of iron.

DCCCCXL. Bile is decomposed by all the acids, which produce an abundant precipitate of resin and albumen, and these substances may be separated by the action of alcohol. It requires but 25 parts of nitric acid to saturate 100 of human bile. When solution of acetate of lead of commerce is added to bile, it is converted into a liquid of a light yellowish colour, which contains no picromel, nor any thing but acetate of lead, and some traces of an animal matter. Human bile appears to be formed of water, a small quantity of yellow matter, albumen, a kind of resin and the salts above mentioned. Its analysis by Thenard* afforded from 1100 parts, 1000.0 of water,

from 2 to 10 of yellow insoluble matter

42.0 Albumen

41.0 Resin

5.6 Soda

4.5 Phosphates, &c. above mentioned.

From 1000 parts Berzelius obtained of

* Mem. D'Arcueil, t. i. Traité de Chimie, t. iii. 630.

Water	-	-	-	-	-	-	-	907.4
Biliary matter	-	-	-	-	-	-	-	80.0
Mucus of the gall bladder dissolved in bile								3.0
Alkalies and salts common to secreted fluids								9.6
								<hr/>
								1000.0*

DCCCCXLI. The bile of different animals differs considerably; that of the ox appears to have been investigated with the greatest precision.

It is a liquid, varying in colour from yellowish to deep green, of a very bitter taste, unctuous and soapy feel, and a specific gravity amounting to about 1.026. On exposure to the air for some time, it undergoes putrefaction, and exhales a foetid odour. It mixes with water in all proportions, forming a solution of a yellow colour; but it does not unite with oils. Its aqueous solution tinges vegetable blues, green; hence it contains an uncombined alkali.

The acids precipitate from bile a yellow matter, insoluble in water, and the largest product is obtained from sulphuric acid. If the acid be added after this precipitation has taken place, picromel, with a portion of yellow matter, subsides. Bile is partly precipitated and in part decomposed by nitric acid, oxalic and hydro-cyanic acids being formed. By chlorine its colour is almost destroyed, and at the same time it is partially decomposed.

When bile is mixed with alcohol, the liquid assumes a green colour, and filaments float in it, which when collected upon a filtre and washed, have the properties of coagulated albumen. The remaining liquid yields on evaporation a green, bitter, fusible, and inflammable substance, which exhibits the properties of resin; hence it has been called the *resin of bile*. It appears to be a compound of picromel and some animal matter.

DCCCCXLII. On exposure to a moderate heat, a quantity of water passes off and leaves a thick, tenacious liquid of a

* Medico-Chirurgical Transactions, vol. iii.

dark brown colour, intensely bitter and deliquescent. When evaporated to dryness, the mass amounts to from $\frac{1}{8}$ to $\frac{1}{9}$ of the whole; it has a deep colour and is soluble both in alcohol and water. If this dried bile be distilled, it yields the usual products. According to the analysis of Thenard, 800 parts of ox-bile consist of

Water	-	-	-	-	-	-	-	700.0
Resinous matter	-	-	-	-	-	-	-	15.0
Picromel	-	-	-	-	-	-	-	69.0
Yellow matter	-	-	-	-	-	-	-	4.0
Soda	-	-	-	-	-	-	-	4.0
Phosphate of soda	-	-	-	-	-	-	-	2.0
Muriates of soda and potash	-	-	-	-	-	-	-	3.5
Phosphate of lime, and perhaps magnesia	-	-	-	-	-	-	-	1.2
Sulphate of soda	-	-	-	-	-	-	-	0.8
Oxide of iron, some traces								

799.5*

DCCCCXLIII. The fixed alkalies, instead of precipitating bile, render it more transparent and less viscid. Solution of acetate of lead precipitates the yellow matter, the resinous part, and the sulphuric and phosphoric acids of the bile; the sub-acetate (Goulard's extract) not only precipitates these, but likewise the picromel, and the muriatic acid. Most of the fatty substances may be dissolved in bile, and this property, as observed by M. Thenard, has contributed to the adoption of the idea, that bile is a species of animal soap. It is owing to the presence of soda, and the triple compound of soda, picromel, and resin contained in it. Hence it is often employed to remove spots of grease from cloths.

DCCCCXLIV. *Biliary calculi*. Solid bodies of different sizes are not unfrequently met with in the gall-bladders of the human species, and of the inferior class of animals. They are called *gall-stones*, or *biliary calculi*. They are depositions

* *Traité de Chimie*, t. iii. p. 626.

from the bile apparently, and when they exist give rise to the disease known by the name of jaundice. They are of different natures, and may be divided into at least two well defined species.

DCCCCXLV. The first species is generally large, and found solitary. It is white, and composed of shining plates, of a soft texture, a greasy feel, and bearing a considerable resemblance to spermaceti. It is sometimes of the size of a hen's egg, and frequently contains a nucleus of a yellow colour. There is a perfect specimen of this kind in the anatomical museum of Harvard University. The density of this species is less than that of water.

With regard to its chemical properties it resembles spermaceti. It melts at the temperature of 278° , and if suddenly thrown upon a hot iron, it becomes liquid, and disappears in a thick white smoke. In this state, if a flame be applied, it takes fire, burns with a dense white flame, and leaves a small coal. It is insoluble in water, but soluble in hot alcohol, from which, as the temperature falls, it is precipitated in white and brilliant plates. It is likewise soluble in oil of turpentine, and nitric acid, and forms with the alkalies a saponaceous compound.

DCCCCXLVI. The second species of biliary calculi is when first formed probably spherical or spheroidal, but as several distinct concretions are usually found together, they are worn by attrition or by pressure into a polygonal shape. They are yellow, with a smooth surface, harder than the preceding species, and formed frequently of laminæ or concentric layers, crystallized in radii. Their specific gravity, at least those which I have in my possession, is rather greater than that of water.* These concretions often exhibit at the centre a nucleus of a whitish colour. In their chemical properties they resemble those of the preceding species. They have

* Some years ago I took from the gall-bladder of a female, who while alive was affected with mania, sixty one concretions of the second kind, each of which was rather larger than a pea.

been considered as composed of a peculiar substance similar to what has been called *Adipocire*. Chevreul considers the matter of the first species of biliary calculi as a peculiar animal substance. He obtained it pure by the action of hot alcohol, and gave to it the name of *Cholosterine*. Its properties we have already detailed, excepting that by the action of nitric acid it acquires acid properties, and has been named Cholosteric acid.

There exist two other species of morbid biliary concretions, but they are comparatively rare. One of them, according to Thenard, consists of the *yellow matter* in an inspissated state; the other is distinguished by its insolubility in alcohol and oil of turpentine, and its not burning with flame when sufficiently heated.

DCCCCXLVII. The uses of bile in the animal œconomy are doubtless very essential; it appears to be necessary to the completion of the digestive process, but the part which it acts is not developed. It is conjectured by Dr. Murray that it may likewise co-operate with the lungs in freeing the circulating blood from its excess of carbon and hydrogen.

SECTION III.

Of Urine.

With the exception perhaps of the blood, no fluid of the animal body has been more accurately examined than urine. The results at the same time have been more definite and satisfactory.

DCCCCXLVIII. The appearances and properties of this excrementitious fluid vary in different persons, and in the same person at different times; but in general it is transparent, of a yellowish colour, a peculiar odour, and a disagreeable saline and bitterish taste. Its specific gravity exceeds that of water. Its odour is affected by peculiar kinds of food. The resinous substances impart to it the odour of the violet. On being allowed to cool and rest for a few hours, it becomes

slightly opaque in consequence of the presence and separation of a portion of mucus from the coats of the bladder. This cloudiness is greater in some diseases than in health, and in *dropsy* and *dyspepsia*, a considerable quantity of albumen and gelatine is precipitated. Urine always changes vegetable blues to red, but after spontaneous decomposition has commenced, it becomes alkaline and gives to vegetable blues a tint of green.

DCCCCXLIX. When allowed to stand for some time, it deposits a reddish sediment, consisting of *Uric acid* and a small proportion of phosphate of lime. Boracic acid is likewise separated. At this time an ammoniacal odour begins to exhale, the liquid runs into the putrefactive fermentation, gives out an intolerably fœtid odour, and is entirely altered in composition. This putrefaction has been inferred to depend principally upon the albumen or mucus which may have been present, for it is rapid in proportion to the amount of these principles. The elements of the substances contained in it combine in such a way as to form salts with ammonia for their basis.

Fresh urine mixes in all proportions with water, but it is partially decomposed by alcohol in large quantity, it becomes turbid and deposits uric acid, earthy phosphates and perhaps other salts. Phosphate of lime is separated from it by ammonia, as likewise a smaller proportion of phosphate of magnesia. Benzoic acid exists in the urine and it may be obtained from it by sublimation. It has been shown by Proust and Vogel, in opposition to Berzelius, that this liquid likewise contains carbonic acid. The presence of sulphuric acid may be detected by adding to urine nitric acid and then dropping into it muriate of barytes; sulphate of barytes will precipitate, and the acid is said by Berzelius to be combined both with potash and soda. Fluuate of lime is also an ingredient of urine.

DCCCCCL. When urine is submitted to evaporation, water is vaporized, which carries with it something that gives it an

unpleasant odour and the property of putrefying. If the evaporation be checked at a certain point and the liquid be allowed to cool, a considerable crystalline mass, coloured brown by urea, will be deposited; by the use of alcohol the colouring matter may be removed, and the salts may be obtained pure and crystallized. These salts consist of phosphates of soda and ammonia, common salt, muriate of ammonia, and sulphates of potash and soda. They were formerly designated by the names of *Fusible salt of urine*, or *microcosmic salt*. Evaporated still further it produces a second crop of crystals, and when it has the consistence of syrup it contains a considerable proportion of urea, together with a deep brown extract, which deliquesces in the air, and on being burnt yields much carbonate of ammonia, and a very saline coal, difficult to incinerate in consequence of the fusibility of the salts which it contains. Urea, as has already been noticed (p. 415.) may be obtained from the syrupy mass by the aid of alcohol; it is the presence of this substance which gives to urine its characteristic taste and odour.

DCCCCLI. When solution of the alkalies is poured into urine, the earthy phosphates are decomposed and their bases are precipitated. Solutions of lime, barytes, and strontian not only decompose these salts, but also combine with and precipitate the phosphoric acid; as well probably as the sulphuric acid of the sulphates. Oxalic acid is the only one of this class which after a time renders urine turbid, and it is in consequence of combining with the lime of the phosphate and forming an insoluble oxalate.

Urine is rendered turbid by infusion of galls, and deposits a compound of gelatine and tannin.

This liquid likewise contains sulphur, for silver exposed to its action acquires a crust of sulphuret of silver.

When urine is distilled, it suffers nearly the same changes as those which take place during its putrefaction. The products are water which is foetid and carbonate of ammonia, ammoniacal salts remain, and gelatine and phosphate of lime

are separated. Urea is very susceptible of decomposition, and the changes are facilitated by the decomposition of gelatine. Acetic acid is one of the products.

DCCCCCLII. From what has been said it is obvious, that the urine is a very compound fluid, that it is very susceptible of decomposition, and that it is characterised by its disposition to form ammoniacal salts. The following table is the result of the analysis of this liquid by Berzelius.

Water	-	-	-	-	-	-	933.00
Urea	-	-	-	-	-	-	30.10
Sulphate of potash	-	-	-	-	-	-	3.71
Sulphate of soda	-	-	-	-	-	-	3.16
Phosphate of soda	-	-	-	-	-	-	2.94
Muriate of soda	-	-	-	-	-	-	4.45
Phosphate of ammonia	-	-	-	-	-	-	1.65
Muriate of ammonia	-	-	-	-	-	-	1.50
Free Lactic acid	}						- 17.14
Lactate of ammonia							
Animal matter, soluble in alcohol and usually accompanying the lactates							
Animal matter, soluble in water							
Urea, not separable from the preceding	}						- 1.00
Earthy phosphates, with a trace of Fluete of lime							
Uric acid	-	-	-	-	-	-	1.00
Mucus of the bladder	-	-	-	-	-	-	0.32
Silex	-	-	-	-	-	-	0.03*
							<hr/> 1000.00

Urinary Calculi.

DCCCCCLIII. It is well known that solid matter is sometimes deposited from the urine in the bladder or its appendages,

* Medico-Chirurgical Transactions, vol. iii.

and gives rise to the disease commonly called the *stone*. The symptoms produced by these deposits are excessively severe, constituting one of the most painful of diseases, and which can be removed only by the most formidable of chirurgical operations. It is therefore a subject of great importance to investigate the nature of these calculi, that means may be discovered of preventing their formation, or if formed, of restraining their growth, or of dissolving and removing them from the body. The efforts of chemists, made in conjunction with those of physiologists, have already produced some favourable results, and it is probable that chemistry alone can furnish the only effectual preventives or remedies to this most painful and dangerous complaint.

The knowledge we have respecting the nature of urinary calculi has been acquired from the researches of Scheele, M. M. Fourcroy and Vauquelin, Dr. Wollaston, Mr. Brande, and Dr. Marcet. In detailing the properties of the different species, I shall avail myself of the recent work of Dr. Marcet, which includes the information obtained from the labours of those who preceded him, as well as that which may be derived from his own experience.*

DCCCCLIV. The species of urinary calculi hitherto observed are eleven in number.

1. *Lithic calculus*. Of a brown or mahogany colour—smooth, sometimes finely tuberculated—formed of concentric layers of the same or of different natures—hard, inodorous—sparingly soluble in hot water, and separating in yellowish particles as it cools. Not acted upon much by ammonia—soluble in liquid alkalies, and precipitated white by acids. Insoluble in sulphuric and muriatic acids, but dissolves in nitric acid, leaving on evaporation a substance of a bright pink colour—not affected by alkaline carbonates—nor but little by lime-water.—Before the blow-pipe, blackens, emits a peculiar odour, and evaporates, leaving a white alkaline ash.

* Essay on the Chemical History and Medical Treatment of Calculous Disorders, 8vo, 1817.

This kind of calculus consists almost entirely of uric acid, and is one of the most common calculi.

2. *Phosphate of lime.* Colour, pale brown—surface, smooth—structure, laminated, of little coherence, and formed of striæ—urged before the blow-pipe it blackens, then becomes white, and melts with great difficulty.

3. *Triple calculus.* Colour, whiter than the preceding—texture, less compact—often appears in the form of white, crystalline sand, discharged in the urine. It constitutes the greater part of calculi which exhibit minute sparkling crystals upon the surface, or between the interstices of other calculous laminæ. Before the blow-pipe, gives out ammonia, diminishes in size, and suffers imperfect fusion. Crystals are tri-lateral prisms, sparingly soluble in water, but soluble in acids, and crystallize when precipitated. Ammonia is disengaged by the alkalies.

This calculus consists of phosphate of magnesia and ammonia.

4. *Fusible calculus.* One of the most common. It is whiter and more fusible than the above, friable—separable into layers—often studded with brilliant crystals of triple phosphate. It is a mixture of simple phosphate and triple phosphate, and often acquires a very large size. The triple phosphate is soluble in acetic acid, and the phosphate in muriatic acid, uric acid in small quantity being left. The solution of the former is precipitated by carbonate of ammonia, and of the latter by oxalate of ammonia. It forms a white vitreous globule before the blow-pipe. This is the kind of stone usually formed around nuclei.

5. *Mulberry calculus.* Consists of oxalate of lime. Colour, dark brown, or nearly black—texture, hard and compact—surface, rough and tuberculated, resembling the fruit of the mulberry—soluble in muriatic and nitric acids—unaffected by caustic alkalies, but decomposed by digestion with their carbonates. Decomposed by heat, quick-lime remaining.

This species likewise contains a small proportion of uric acid, and phosphate of lime.

6. *Cystic oxide* has a yellowish semi-transparency, and a peculiar glistening lustre, and appears as a confusedly crystallized mass. Exposed to heat it gives out a peculiar and fœtid smell. It unites both with acids and alkalies, and as it forms carbonic acid during its distillation, it must contain oxygen. Its compounds with acids and alkalies both crystallize. It is not a common calculus.

7. *Alternating calculus*. This calculus consists of two or more of the preceding species, arranged in alternate layers.

8. *Compound calculus*. In this species the ingredients are so intimately mixed as not to be separable without chemical analysis.

9. *Calculus from the prostate gland*. This is of a yellowish brown colour, of a spheroidal form, about the size of a pea, and consisting of phosphate of lime.

10. *Xanthic oxide*. Colour, reddish cinnamon—texture, compact, hard, and laminated—surface smooth. It is very rarely met with.

11. *Fibrinous calculus*. Consisting of or rather containing a large proportion of fibrin. It is small and uncommon.

DCCCCLV. From what has been mentioned it appears that the component parts of urinary calculi are uric acid, phosphate of lime, phosphate of ammonia and magnesia, oxalate of lime, cystic oxide, xanthic oxide, fibrine, and an animal matter. Of these, uric acid is the most common, next to which are the fusible calculus, and the mulberry calculus or oxalate of lime. The singular fact has been likewise ascertained by Dr. Marcet, that notwithstanding the hardness and rough tuberculated surfaces of the oxalate of lime, which might be supposed to occasion the most dangerous symptoms, the greatest proportion of deaths has taken place in those affected with the mixed, or fusible kind. "It seems to show," says he, "that it is not so much the mechanical irritation of the stone, as the particular diathesis of the urinary secretions, which influences the event of the operation."

The analysis of these calculi has led to the modes of treatment which are founded entirely upon chemical principles. Whenever the lithic or uric secretion predominates, the alkalis are the appropriate remedies ; and the acids particularly the muriatic, are the agents to be resorted to, when the calcareous or magnesian salts prevail in the deposit. Dr. Marcet condemns the use of magnesia, and recommends carbonate of soda, coinciding in this respect with the opinion of Mr. Brande.

Concretions which are formed around the small joints in gouty persons, and called *chalk stones*, have been proved by Dr. Wollaston to be composed of uric acid and soda.

DCCCCLVI. *Diabetic urine*. In certain morbid states, either of the whole system, of the digestive, or of the urinary organs, the quantity of urine daily evacuated is not only greatly increased, but has a distinctly sweetish taste. Hence to this disease has been given the name of *Diabetis Mellitus*. In some cases however, though the disease exist, the urine contains little or no saccharine matter.

The urine of diabetic patients is free from urea and uric acid, and exhibits but faint traces of a phosphate or sulphate. It has but little effect upon vegetable colours, and hence the proportion of free lactic acid must likewise be exceedingly small. In fact its constituents appear to be water, a saccharine matter, and common salt. The proportion of sugar varies at different times, and in different persons, the quantity being from $\frac{1}{30}$ to $\frac{1}{17}$ of the whole weight ; in some cases however it is prodigiously large, and Mr. Cruickshanks obtained no less than 29 ounces from the urine of a diabetic patient in one day. The thirst in this disease is very great, but the quantity of urine evacuated is often greater than that taken into the stomach. From the experiments of Chevreul, it appears that this saccharine matter is analogous in properties to the sugar of grapes. It may be readily obtained by pouring into the urine a solution of Goulard's extract of lead, filtering, and evaporating the liquid to the consistence of a

syrup. It will granulate in a few days. According to Dupuytren and Thenard, when the disease begins to subside it is indicated by a quantity of albuminous matter which appears in the urine, and continues to increase for several days; it then ceases to be produced, and the other constituents of urine begin to appear, such as urea, uric acid, &c.

It is the general opinion of physiologists that the causes which create this disease exist in the digestive organs, and that it is continued by that kind of food which most readily furnishes the elements of sugar. Experience has proved that it is kept up by the use of vegetable diet, and that even when the cure is almost completed, it may be retarded for a time, by indulgence in a small quantity of food of this nature. Hence to remove it, a diet, consisting altogether of animal matter, has been found most effective, and it should be persevered in for a long time.

SECTION IV.

Of Bone.

DCCCCLVII. The bones are the most solid parts of animals; they constitute the animal frame, serve as points of attachment to the muscles, which are the organs of motion, and afford support to the softer solids.

The general structure of bone is the same, though it is modified by the form and the uses to which it is destined. It is white, lamellated, and inflexible. The bones are hardest at the surface; the internal parts particularly of those which are cylindrical are cellular, as well likewise as their ends, and contain a medullary substance, called marrow. Their specific gravity is rather more than twice the density of water. They are vascular, and covered by a membrane called the periosteum.

DCCCCLVIII. The substances which compose the bones are gelatine, fat, cartilage, and earthy salts.

If a bone recently taken from a skeleton be boiled in water, a portion of fatty or oily matter is first disengaged, the liquid is found to contain gelatine, and if the proportion of water have not been too large, the decoction on cooling will be converted into jelly. In this way the soluble animal substances are removed from the basis of the bone or the earthy matter.

The latter may likewise be separated from the former by the action of an acid. If recent bone, deprived of its periosteum, be put into muriatic acid diluted with water, the earthy salts will be acted upon and gradually dissolved, while the membranous parts will remain unchanged in form or properties. This method has been recently practised in France to obtain gelatine in an æconomical way, the latter after the removal of the former requiring merely to be well washed with cold water, before being boiled with water. The quantity of gelatine amounts to about $\frac{1}{16}$ the weight of the bone. Hence it is that bones broken into fragments or pounded, and then boiled in water, form a nutritious soup.

Bone may likewise be deprived of its gelatine and other soft animal substances by what is called calcination, which is simply exposing it to a red heat until it ceases to smoke and becomes white. In this state it is porous, and still retains its original form, but loses about $\frac{5}{7}$ of its weight. It constitutes the *earth of bones* of the earlier chemists. When bones are distilled in close vessels they yield water, oil, different gases, together with a small proportion of acetate, and prussiate of ammonia, and a large quantity of sub-carbonate of ammonia, and the residue, when urged by an intense heat, becomes vitrified. Hence bones are employed for the purpose of procuring *salt of hartshorn*, and *sal ammoniac*.

DCCCCLIX. When calcined bone in powder is put into a sufficient quantity of muriatic acid, effervescence at first takes place, from the disengagement of carbonic acid, and the mass is then dissolved. If pure ammonia be added, a white precipitate is formed, which dissolves with ease and

without effervescence in nitric or muriatic acid. It is a mixture of phosphate of lime, and phosphate of magnesia. Solution of nitrate of barytes poured into the liquid throws down a white powder insoluble in muriatic acid, and consisting of the barytes in union with sulphuric acid. Carbonate of ammonia will then occasion a precipitate of carbonate of lime. Hence it appears that the earthy part of bone consists of phosphate of lime, sulphate of lime, carbonate of lime, and phosphate of magnesia. Of these the first is the most abundant, as will appear from the following analysis by Berzelius.*

Phosphate of lime	-	-	-	-	-	81.9
Fluate of lime	-	-	-	-	-	3.0
Lime	-	-	-	-	-	10.0
Soda	-	-	-	-	-	2.0
Carbonic acid	-	-	-	-	-	2.0
Phosphate of magnesia	-	-	-	-	-	1.1
						<hr/> 100.0

DCCCCLX. “When the gelatine of bones has been removed by boiling, and their earthy parts by acids, there remains a soft white elastic substance, possessing the figure of the bone, and known by the name of *cartilage*. From the experiments of Hatchett it appears that this substance has the properties of coagulated albumen.”

Ox-bone consists, according to Fourcroy and Vauquelin, of

Animal matter	-	-	-	-	-	51.00
Phosphate of lime	-	-	-	-	-	37.7
Carbonate of lime	-	-	-	-	-	10.0
Phosphate of magnesia	-	-	-	-	-	1.3
						<hr/> 100.00

The substance of the Teeth consists of bone, but the *enamel* differs from it essentially in containing no cartilage.

* Thomson's Chemistry, iv. 457. 5th edit.

This has been proved by Mr. Pepys, who found it composed of

Phosphate of lime	-	-	-	-	-	78
Carbonate of lime	-	-	-	-	-	6
Gelatine	-	-	-	-	-	16*
						<hr/>
						100

Berzelius seems to have proved that fluoric acid is likewise an ingredient of enamel. The same acid constitutes a part of ivory.

Mr. Pepys has also analysed the teeth at different periods of their growth, and obtained the following results.

	Roots of the Teeth.		Teeth of Adults.		First teeth of Children.	
Phosphate of lime	-	56	-	64	-	62
Carbonate of lime	-	4	-	6	-	6
Cartilage	-	28	-	20	-	20
Loss	-	10	-	10	-	12
		<hr/>			<hr/>	<hr/>
		100			100	100

Bones, as has been observed, are employed to extract gelatine and for the production of carbonate and muriate of ammonia. They are likewise used in many of the mechanical arts, and the residue, after their distillation, which consists of charcoal and the earthy salts, constitutes the *ivory black* of the painters.

DCCCCLXI. Shell is analogous in its composition to bone. It has been divided by Mr. Hatchett into two species, the *Porcellaneous*, which is compact, brittle, hard, of a smooth and variegated surface, and bearing a considerable resemblance to porcelain, and the *Mother-of-pearl shell*, which is tougher, shining and often variegated. The first species decrepitates in the fire and loses the colour of its surface,

* Fox on the Teeth.

but emits no smoke nor odour ; it is soluble with effervescence in muriatic acid, forming a transparent solution, from which a carbonated alkali precipitates carbonate of lime. The second species when heated gives out the odour of burning horn, and is only partially soluble in muriatic acid, leaving albumen in layers and an outer epidermis. In some specimens of this kind the albumen is tough and indurated, in others soft and delicate.

The substance of *Pearls* consists, according to Mr. Hatchett, of

Carbonate of lime	-	-	-	-	-	66
Animal matter	-	-	-	-	-	34
						<hr/> 100

Mother-of-pearl is composed of the same ingredients in the same proportions.

Lobster shell contains of

Carbonate of lime	-	-	-	-	-	60
Phosphate of lime	-	-	-	-	-	14
Cartilage	-	-	-	-	-	26
						<hr/> 100

The following, according to Vauquelin, is the composition of hen's egg-shell.

Carbonate of lime	-	-	-	-	-	89.6
Phosphate of lime	-	-	-	-	-	5.7
Animal matter	-	-	-	-	-	4.7
						<hr/> 100.0

The horns of the buck and the hart are similar in composition to bone, but contain a larger proportion of animal matter.

SECTION V.

Of Horn, Nails, Hair, Silk, &c.

DCCCCLXII. Horn is a compact substance of a close and smooth texture, elastic and transparent in thin plates, easily cut with a knife, but so tough as not to be reducible to powder. In its usual state it possesses some hardness, but when gently heated it is soft and flexible, and may be moulded into any form.

When boiled for a long time in water, it yields a quantity of gelatine, and the substance which remains has the character of hardened albumen, or concrete mucus. Horn appears to be almost homogeneous, for from 500 grains of ox-horn Mr. Hatchett obtained only 1.5 grain of ash, of which about $\frac{1}{2}$ consisted of phosphate of lime. The substance of *hoof* is analogous in composition to that of horn.

The same observation applies to *nails*. They are not soluble in water, but are decomposed by the acids and alkalis, and are composed of indurated albumen with a minute proportion of phosphate of lime.

DCCCCLXIII. The structure of *hair* is tubular; it appears smooth to the eye even when aided by a microscope, but from its disposition to entangle, it has been supposed to be covered with scales or consisting of imbricated zones. It is not equally smooth when rubbed in different directions.

Vauquelin executed a series of experiments upon hair and obtained the following results. Though insoluble in common circumstances in boiling water, yet when aided by pressure, as in Papin's digester, it may be dissolved, and even decomposed. During the solution there separates a substance of an oily nature; infusion of galls and solution of chlorine produce copious precipitates from the liquid, and it is rendered turbid by the acids, when not in excess. Its concentrated solution does not gelatinize on cooling. Hair is dissolved by a weak solution of potash, and hydro-sulphuret of ammonia

evolved. If the hair be black, the oil separated has a dark colour; if red, a yellow colour, and both produce a little sulphur and iron. Sulphuric and muriatic acids act upon hair; they become red and then dissolve it. Nitric acid is rendered yellow; an oil, black or yellow, according to the colour of the hair, is disengaged, and the solution contains oxalic acid, together with a little sulphuric acid, bitter principle, and iron. By chlorine, hair is at first whitened and then reduced to a substance of the consistence of turpentine, which is partly soluble in alcohol.

By the action of hot alcohol on black hair two kinds of oil are evolved, one which is white, and precipitates in shining scales as the solution cools, the other obtained by evaporation, is of a grayish green colour, and gradually becomes solid. Alcohol likewise extracts from red hair two kinds of oil, one white, the other blood-red, and the hair then assumes a chestnut brown colour. The substances afforded by burning it are iron, manganese, phosphate, sulphate, and carbonate of lime, muriate of soda, and silex. Magnesia is found in the ashes of white hair.*

From these facts it appears that the colour of hair depends upon the presence of an oil, and perhaps likewise of sulphuret of iron, as stated by Vauquelin.

Its composition is similar to that of horn, consisting, according to Vauquelin, of inspissated mucus, or as Hatchett affirms, of coagulated albumen.

Wool and feathers are nearly of the same nature as hair.

DCCCCLXIV. *Silk* is the product of different species of caterpillars, particularly the *Phalena Bombyx*, and the *Phalena Atlas*, natives of China, but now domesticated in Europe. When spun by the animal, it is in the form of small bags, called *cocoon*, white with a shade of yellow more or less intense. In its natural state it is covered with a kind of varnish which gives it a glossy appearance, is soluble in wa-

* Nicholson's Journal, vol. xv. p. 141.

ter but not in alcohol, and yields a precipitate with tannin. It amounts in weight to nearly $\frac{1}{3}$ of the weight of the whole silk. When the solution is evaporated, a solid substance of a black appearance, brittle and shining, is obtained.

The colouring matter of silk appears to possess the properties of a resin. It is soluble in alcohol, of a yellow colour, fusible at 86° , has a strong smell, is insoluble in water, but may be dissolved by the alkaline and soapy solutions. It is bleached by exposure to light. The silk when deprived of this resin becomes colourless and beautifully white. This resinous matter amounts to about $\frac{1}{60}$ of the weight of the silk.

Silk before it is manufactured is freed from the varnish and resin by the action of alkalies, alcohol, and acids, particularly muriatic acid diluted.

In this state it is not acted upon very readily by reagents. It is insoluble in water and alcohol, but may be dissolved by the assistance of heat in alkaline solutions, ammonia being evolved. It is dissolved likewise by the mineral acids, and partly decomposed. By the action of nitric acid it is converted into oxalic acid, a fatty substance, and *amer* or bitter principle. It is blackened and decomposed by heat, but does not readily burn with flame, and when subjected to destructive distillation, it yields the usual products, the proportion however of carbonate of ammonia being very large. It is not very liable to spontaneous decomposition.*

SECTION VI.

Of Cartilage, Tendon, Ligament, &c.

DCCCCLXV. Cartilage is the substance which covers the ends or articulating surfaces of bones. It is of an uni-

* The silk-worm produces an acid liquid which was considered by Chaussier as a peculiar acid, and called by him *bombic acid*; it is questionable however whether it be any thing more than acetic acid disguised.

form appearance, white, with a pearly lustre, dense, flexible, translucent and smooth. It appears to determine the form of bones, for before the deposition of the earthy salts, it has the figure of the bones, but is soft and flexible. Cartilage by long boiling is soluble in water; it is acted upon with difficulty by the acids, nor is it very susceptible of spontaneous decomposition. From the experiments of Mr. Hatchett, it would appear to consist almost entirely of indurated albumen, it contains gelatine, and a minute proportion of phosphate of lime.

DCCCCLXVI. Tendons are the hard, strong *sinews*, which unite the muscles to the bones. Their surface is brilliant and their substance pearl-coloured. When boiled in water, they become soft and glutinous and may even be completely dissolved. The solution, if sufficiently strong, gelatinizes on cooling. Hence they consist of gelatine in a state of organization, and may be considered as furnishing a very nutritive diet when in solution.

DCCCCLXVII. Ligaments are fibrous bands, the use of which in the animal œconomy is to connect the ends of bones with each other and to form and support the joints. Hence they possess great strength. They are white, fibrous, somewhat elastic and dense in their structure. They may be boiled in water for a long time without undergoing solution or losing their form or strength. They probably consist of indurated albumen.

DCCCCLXVIII. Membranes are broad and thin expansions of a semi-transparent substance, which constitute a large part of the hollow organs of the body, or which cover the surfaces of other organs. They are soft and flexible, white and elastic. They are soluble in water, and have the properties of gelatine. Isinglass, as has already been mentioned, consists of the air bladder, and sound of the sturgeon, &c. Membranes of course combine with tannin, and may thus be converted into leather.

SECTION VII.

Of Skin.

DCCCCLXIX. Skin considered physiologically consists of three parts, the *cuticle* or *epidermis*, a thin and delicate membrane filled with pores, which constitutes the external covering, the *rete mucosum*, or a thin layer of soft pulpy substance, on which the colour is supposed to depend, and the *cutis vera*, or true skin, which is thick and elastic. Below this resides the cellular tissue.

The cuticle is transparent. It is insoluble in water and alcohol, but may be easily dissolved in alkaline solutions. Sulphuric and muriatic acids have but little effect upon it, but by nitric acid it is rendered yellow. When nitric acid is applied to any part of the living body, a yellow spot is produced and the cuticle in a few days falls off. It is likewise acted upon by lime. It is inferred and justly to consist of indurated albumen. It is this membrane which is raised by the irritation of blisters.

DCCCCLXX. The cutis or true skin is thicker and denser in its texture, and is composed of fibres interlaced, and possessing a very considerable degree of strength. They are flexible and elastic. When macerated in cold water, the cutis swells up, and if the water be then heated to and kept at 212° for some time, it dissolves and forms a solution which on cooling is converted into a jelly. Moist skin and its decoction soon run into the putrefactive fermentation, provided the temperature to which they are exposed be sufficiently high. But when dry, it may be preserved an indefinite time. Skins consist almost entirely of gelatine, but as Mr. Hatchett has found, there is considerable difference in the manner in which they are acted upon by reagents, and in the consistence which they give to water. Skin is insoluble in alcohol. It is dissolved by the alkalies, and by the diluted acids.

It is decomposed by nitric acid. When exposed to heat it contracts in bulk, then swells up, emits a fœtid odour, and leaves a charcoal difficult to reduce to ashes; if distilled, it yields the same products as fibrin.

DCCCCLXXI. The substance of skin combines with tannin and forms a compound perfectly insoluble in water. This compound is leather, and its mode of preparation has been already described.

DCCCCLXXII. The colour of the skin resides in the substance which is interposed between the *epidermis* and the *cutis vera*. It is called *rete mucosum*. Dr. Beddoes relates the curious fact, that chlorine or oxy-muriatic acid is capable of destroying, at least for a time, the colour of the negro, for the fingers of an African, having been held some time in a watery solution of this gas, became nearly white, but in a few days it reassumed its original colour.

SECTION X.

Of Muscular Substance.

DCCCCLXXIII. The muscles are the organs of motion, and consist of bundles of fibres placed longitudinally, with cellular substance interposed between them. These fibres are of a reddish colour, and covered with a delicate membrane. The colour however is owing to the presence of blood, for when sufficiently washed, they become white. The liquid assumes a dark red colour; if heated, albumen coagulates and separates in flakes, a small quantity of fat rises to the surface, and if the solution be then sufficiently concentrated by evaporation, it concretes on cooling into a jelly. Hence it appears that muscular fibre is composed of fibrin, albumen, gelatine and fat. When the jelly above mentioned is evaporated to dryness and treated with alcohol, a peculiar substance, according to Thouvenal, is obtained, which he called an extract, and which when solid is of a brownish red col-

our, a pungent and acrid taste, and of an aromatic odour. By the action of heat it acquires the taste and odour of caramel or burnt sugar.

When flesh is burnt to charcoal, there are found in the residue carbonate of lime, and phosphate of lime, soda, and ammonia. From 500 parts of beef muscle Mr. Hatchett obtained 25.6 parts, composed principally of the above salts.

A portion of these salts is dissolved when flesh is long boiled in water.

DCCCCLXXIV. As the basis of muscular fibre is fibrin, the action of chemical reagents upon it is the same as upon that principle. When boiled with diluted nitric acid it is partly dissolved and a gaseous fluid, consisting of azote with a small proportion of nitric oxide, and carbonic acid, is evolved. The solution is yellowish, and when cool, a white and fatty substance floats upon the surface. The matter which has not been dissolved is soluble in hot water, to which it gives a yellow colour, and acid properties. It is soluble in the alkalies, giving to them a blood-red colour, and separable from them in yellow flakes by acids. These flakes have a greasy feel, are adhesive, and possess a bitter taste and rancid odour. This substance, according to Fourcroy and Vauquelin, combines with the alkalies, and is even capable of decomposing their carbonates. Hence they concluded that it contained an acid, which, in subsequent experiments, was separated by alcohol, which dissolved a fatty matter and left the first pure. To this they gave the name of *yellow acid*. It is of a yellow colour, capable of reddening vegetable blues, combines with some of the salifiable bases, does not melt on exposure to heat, but is decomposed and gives out a foetid ammoniacal odour. Experiments were likewise made by these chemists upon the acid liquid, in the course of which they succeeded in procuring fulminating crystals similar to those which are produced by the action of nitric acid upon indigo. One of the products also of their experiments was *amer*, or bitter principle.

The two substances, the yellow acid and the bitter principle, have been regarded by Chevreul, Thenard, and Berzelius as peculiar compounds of nitric acid and fibrin.

Berzelius has analysed muscular fibre and obtained the following results.*

I. *Solid matters.*

Fibrin, vessels, and nerves	-	-	-	15.8
Cellular matter, dissolved by boiling	-	1.9	-	
				<hr/>
	17.7	-	-	17.7

II. *Liquid bodies.*

Muriate and lactate of soda	-	1.80	
Albumen, and colouring matter of the blood	- - - -	} 2.20	
Phosphate of soda	- - -		
Extract	- - - - -	0.15	
Albumen, holding in solution phosphate of lime	- - -	} 0.08	
Water and loss	- - - -		
		<hr/>	
		82.30	- - 82.30
			<hr/>
			100.00

DCCCCLXXV. Berzelius affirms that the *extract* of Thouvenal is a compound of lactic acid, an alkaline lactate, and a peculiar animal matter which always accompanies the lactates. This compound, together with gelatine and some of the salts, is soluble in water, and hence when meat or in other words the muscular parts of animals are boiled, a solution is made which constitutes *broth* or *soup*. The peculiar taste is supposed to depend upon the presence of the extractive matter. By the operation of heat this becomes somewhat altered and is at the same time retained, and hence roasted meat has a higher flavour than that which has been boiled.

* Mem. D'Arceuil, t. i. p. 333; or Thomson's Chemistry, vol. iv. p. 474.

The muscles of different animals obviously differ much from each other, but this may depend more perhaps upon the relative proportions of the substances above mentioned, than upon the presence of other animal principles.

SECTION XI.

Of Brain and Marrow.

DCCCCLXXVI. The brain is composed of two substances ; one external, called the cortical or cineritious part, the other internal, and designated by the name of medullary part. The whole is of a soft consistence, pulpy, of a fatty or soapy feel, and of a faint but peculiar odour. Its specific gravity is greater than that of water. The medullary part, which is white, has a close and uniform texture.

When dried by the heat of a water-bath, it loses nearly $\frac{4}{5}$ of its weight, and the remainder burned in a platinum crucible decrepitates, melts, then smokes and exhales the odour of an empyreumatic oil. It takes fire in this state, burning with a yellowish white and large flame, and deposits an abundance of light charcoal. From 2 ounces of dried brain Vanquelin obtained 78.7 grains troy of charcoal, which, after exposure even to a white heat for an hour, lost but about 6 grains. This mass washed with boiling water and then dried weighed 36.5 grains, so that the water dissolved about one half. The aqueous solution exhibited acid properties. By subsequent experiments it was proved that the incineration of cerebral matter produced phosphates of potash, lime, and magnesia.

Brain, when excluded from the air, may be preserved for a long time, but on exposure in its moist state to the atmosphere for a few days, it undergoes spontaneous decomposition, exhales a very fœtid odour, similar to that of putrid cheese, evolves sulphuretted hydrogen, and occasions a sensible alkalinity in the liquid in which the putrefaction is going on. On filtering the fluid, it becomes transparent, of an amber colour,

having an extremely disagreeable smell, and occasions with acids a white flocculent precipitate. When filtered and distilled, yellow flocks separate, and reduced to $\frac{1}{8}$ by further evaporation, it exhibits acid properties. Ammonia throws down from it an ammoniaco-phosphate of magnesia.

The fatty portion of the brain appears to undergo no alteration during this putrefaction.*

DCCCCLXXVII. Cerebral matter, or a portion of it, is soluble by trituration in water, and the liquid when heated nearly to boiling, after being filtered, lets fall a flocculent precipitate, which has the characters of albumen. The same effect is produced by acids and alcohol. The remaining liquid affords phosphate of soda.

When cerebral matter is mixed with five times its weight of alcohol, macerated for twenty-four hours, heated to its boiling point, and then filtered, a greenish coloured liquid is obtained, which on cooling deposits a white matter, partly in flakes and partly in plates. Water poured into the filtered liquid renders it milky. The alcoholic solution on evaporation deposits an oily matter yellowish and liquid, which, when washed with hot water, has a reddish brown colour, an odour similar to that of the brain, but stronger, and a taste resembling that of rancid fat. It forms an emulsion with cold water, from which it is precipitated white by acids. It is coagulated by infusion of galls. Alcohol dissolves this oily matter. Left to itself, it putrefies, and on exposure to heat it melts, blackens, and exhales the odour of burning animal matter. Its coal affords phosphoric acid.

DCCCCLXXVIII. The white matter deposited from alcohol as it cools, after having been digested on brain, is a soft solid, of a greasy, glutinous feel, and of a brilliant appearance like satin. It melts on exposure to heat, though it does not become so fluid as tallow. It is soluble in hot alcohol, but again separates as the solution cools. It becomes yellow on exposure to the solar rays. When exposed to heat in a

* Vauquelin. *Annals of Philosophy*, i. p. 332.

crucible it takes fire, burning with a great deal of smoke and flame, and leaves a mass which has acid properties. This acid is phosphoric, and from the results of his experiments M. Vauquelin infers that this fatty matter contains phosphorus combined with it. "The proportion of it is very small—I estimate its quantity not to exceed $\frac{5}{100}$ of a part; but if we subtract the humidity of the brain, and only consider the dry residuum, in that case the phosphorus may be considered as amounting to $\frac{1}{60}$ part of the whole."

It is inferred, however, by Dr. John, from his experiments, that it is not phosphorus, but phosphate of ammonia.

The *oily* matter above mentioned, which has the odour of the brain, is similar to the Extract of Thouvenal, which we have already mentioned in the preceding section. Thenard has considered it as a peculiar and distinct substance and given to it the name of *osmazome*.*

DCCCCLXXIX. After alcohol has abstracted every thing soluble from brain, there remains a grayish white mass in flocks, which has the odour of fresh cheese, in the proportion of 81 parts to 400 of cerebral matter. On drying, it assumes a gray colour, a semi-transparency, and a fracture similar to that of gum arabic. In water it increases in bulk, is partly dissolved, and soon runs into the putrefactive fermentation. It is soluble in caustic potash, without the disengagement of ammonia, the solution is slightly brown, and is decomposed by acids. Acetate of lead occasions a dark brown precipitate, and thus shows the presence of sulphur. The other properties of this residue leave no doubt that it is identical with albumen.

The mass of the brain then, says Vauquelin, is composed of the following substances.

1. Two fatty matters, which are probably identical.
2. Albumen.
3. Osmazome.

* Probably, as Dr. Thomson suggests, from *οσμη*, *smell*, and *ζωμος*, *broth*.

4. Different salts, among others phosphates of potash, lime, and magnesia, and a little common salt.
5. Phosphorus.
6. Sulphur.

These are inferred to exist in the following proportions.

1. Water	-	-	-	-	80.00
2. White fatty matter	-	-	-	-	4.53
3. Reddish do. do.	-	-	-	-	0.70
4. Albumen	-	-	-	-	7.00
5. Osmazome	-	-	-	-	1.12
6. Phosphorus	-	-	-	-	1.50
7. Acids, salts, and sulphur	-	-	-	-	5.15
					100.00*

Marrow.

The following account of marrow is from the experiments of Berzelius, as detailed by Dr. Thomson.†

DCCCLXXX. The hollow of the long bones in living animals is filled with a peculiar species of fat matter, to which has been given the name of *marrow*. In some it is red, while in others it is yellow.

Marrow freed from its impurities, by being boiled in water, afterwards filtered, collected, melted in water, and strained through a cloth, is white with a shade of blue, and of a taste insipid, but rather sweetish. It softens in the hand, melts at 113°, and on cooling slowly, concretes like oil in spherical globules. It burns with a flame like tallow. When subjected to distillation it affords a yellowish and transparent oil, carbonic acid, water, and olefiant gas. Then succeeds a white solid oil, with less quantities of gaseous fluids, and this oil does not become dark coloured as happens when tallow is distilled. It has a disagreeable smell, amounts to 0.3 of the

* Annals of Philosophy, vol. i. p. 32.

† System of Chemistry, iv. 485.

marrow distilled, reddens vegetable blues, and when boiled in water gives out sebacic acid.

This oil combines with alkalies and their carbonates, and with the latter forms a snow-white soap, insoluble in water, though it increases in bulk in that liquid. It likewise forms insoluble soaps with the earths.

The water distilled over in this process is colourless, has a fœtid and sour smell, and an empyreumatic odour. It contains acetic acid, empyreumatic oil, perhaps benzoic acid, but no ammonia. The gaseous matters, which contain neither sulphur nor phosphorus, amount in weight to $\frac{1}{10}$ of the marrow distilled. They are carbonic and olefiant gases. The coal left in the retort amounts to 0.05 of the marrow, and contains traces of phosphate of lime, carbonate of lime, and soda.

Sulphuric acid dissolves marrow; the solution looks like a brown syrup, and the marrow is separated unaltered by the addition of water.

It is rendered yellow by diluted nitric acid, and dissolved by it when concentrated.

It combines with the alkalies and forms soaps. Marrow is soluble in small proportion in alcohol and ether when hot, but is precipitated as the solution cools.

Marrow, from the thigh bone of an ox, was found by Berzelius to be composed of the following substances.

Pure marrow	-	-	-	-	-	0.96
Skins and blood vessels	-	-	-	-	-	0.01
Albumen	}	-	-	-	-	0.03
Gelatine						
Extractive						
Peculiar matter						
Water						<hr/> 1.00

From the preceding detail it appears that pure marrow is a species of fixed oil, possessing peculiar properties, and approaching somewhat to butter in its nature.

CHAP. III.

OF THE SPONTANEOUS DECOMPOSITION OF ANIMAL
SUBSTANCES.

DCCCCCLXXXI. When an animal dies, a new series of action commences, the elements of the body enter into other arrangements, the organized structure is gradually destroyed, and there remains nothing but a shapeless mass of common matter, diminished both in bulk and weight. This series of spontaneous decomposition is designated by the name of Putrefaction. It is the provision established by the Author of nature to keep in circulation the elements of vegetables and of animals, to furnish materials for the growth of new systems, and to cover the surface of the earth with organized and living beings.

DCCCCCLXXXII. Like the analogous process in vegetables, animal putrefaction requires certain conditions for its commencement and continuance. These are, 1. the presence of moisture, 2. a certain range of temperature, and 3. the presence of oxygen or atmospheric air.

Putrefaction proceeds with a slowness proportional to the dryness of the subject, and when a substance of an animal nature is perfectly dry, it may be preserved an indefinite time without change. A great quantity of water likewise diminishes the tendency to putrefaction, and when in such case decomposition proceeds, the results differ more or less from what is usually observed.

But even if water be present in the most favourable proportion, this spontaneous process will not go on, unless it be aided by a certain degree of heat. Meat resists putrefaction in proportion as the temperature is reduced, and if it be frozen, it may be preserved for years. This fact is well known in all cold countries, and it is the usual mode by which provision of an animal kind is preserved. The time that animal

matter may be thus kept is indefinite, but it must be long, for a few years ago the body of a rhinoceros, nearly in a perfect state, was found enveloped in ice on the coast of Norway, and it is supposed that it must have lain there for ages. The higher the range of atmospheric temperature, the more speedy is the decomposition. Hence in tropical climates flesh will begin to putrefy in a few hours, provided its moisture be not rapidly evaporated.

Atmospheric air is not perhaps essential to putrefaction ; but if it be excluded, the results differ in a considerable degree from those under common circumstances. Carbonic acid retards the process, and if the air be totally excluded, the animal matter may be preserved a much longer time.

DCCCCLXXXIII. The series of changes which takes place in common putrefaction is as follows. The mass assumes a dull red or livid appearance, a *musty* odour exhales, and a thin serous fluid oozes from its surfaces. The texture of the muscular fibre becomes softer, and it may be torn with a comparatively slight force ; the smell from it becomes offensive, and if in water, it is surrounded with air-bubbles which rise to the surface and disappear. These changes continue to advance, the colour varies to dull green, the odour is insupportable, the organized structure of the mass is gradually destroyed, it diminishes in bulk, gives out a quantity of ammoniacal gas, and finally falls into a dark brown friable kind of mould, which has a peculiar but not powerful odour.

During the whole process of decomposition, elastic fluid in considerable quantity is formed and disengaged. It is a mixture of phosphuretted, sulphuretted, and carburetted hydrogen gases, ammonia, or sub-carbonate of ammonia, carbonic acid, aqueous vapour, and azote. Their elements may be in binary combination, or what is not improbable, they may be united in ternary or quaternary compounds in modes with which we are as yet unacquainted, and forming compounds, of the properties of which we are still ignorant. The more offensive odour emitted during the putrefaction of

animal than of vegetable substances, may perhaps depend upon the presence in the former of sulphur and phosphorus.

DCCCCLXXXIV. If meat be exposed for some time to the temperature of 212° in a close vessel, and be completely excluded from the air, it may be prevented from putrefying for a long time. M. Appert has applied this fact to the preservation of different animal substances. His process consists in putting the article into a glass vessel, which is corked tightly, and covered with a cement of cheese and lime, so as to be perfectly air-tight, and of sufficient strength to withstand a considerable expansive force operating from within, and then immersing the vessel in water which is made to boil. When the ebullition has continued sufficiently long, the vessel is removed and the mouth is again secured so as to prevent the access of the smallest quantity of air. In this state cream and other animal substances have been sent to distant parts of the world, and have still preserved their sweetness.

It would seem that this suspension of the putrefactive process is owing partly to the exclusion of atmospheric air, partly to the combination of the oxygen of the small quantity of air contained in the vessel with some of the elements of the substance, and in part to some change in the animal matter itself, in consequence of exposure for some time to a comparatively high temperature.

DCCCCLXXXV. In certain circumstances the results of this putrefactive process are so modified that a substance intermediate between wax and fat appears to be formed, and hence Fourcroy gave to it the name of *Adipocire*. It is produced in those situations in which dead bodies in considerable numbers have been buried together, and have been undisturbed for years. The fact was first discovered in consequence of breaking up the burial ground of the Innocents at Paris, in which the dead bodies had been deposited in pits, each containing from 1000 to 1500. The viscera in these bodies had disappeared, the brain was little, if at all changed,

while the whole of the muscular substance had been converted into adipocire.

Fourcroy describes this substance as white, soft, and greasy to the feel, and fusible at a moderate heat. He considered it as an ammoniacal soap, for on analysing it there were found in it a fatty matter, ammonia, and a little phosphate of ammonia and lime. It affords by the acids which decompose it, a fatty, oily, and fusible precipitate, which when melted and allowed to cool concretes into crystalline laminae, possessing properties analogous to those of spermaceti. It is inflammable, but unless purified, it produces while burning a disagreeable smell. It loses its white colour on exposure to the air, and if dried quickly, assumes a brown colour.

It was discovered afterwards by Dr. Gibbes of Great Britain, that the conversion of muscular substance into adipocire might be effected by exposing lean flesh for some time to a stream of water, and he even attempted on a large scale the formation of this substance, for the purpose of manufacturing it into candles, &c. But the establishment became obnoxious in consequence of the putrid odour exhaled during the decomposition of such considerable quantities of animal matter.

One species of biliary calculi, as has been already noticed, (p. 461.) consists of adipocire in a very pure state.

DCCCCCLXXXVI. M. Gay-Lussac has lately attempted to show, that the apparent conversion of animal bodies into fat or adipocire is merely a deception; and that it is owing only to the wasting away of the muscular fibre, while the fat remains. He kept fibrin of the blood in water which was renewed every day for three months, at the end of which it had entirely disappeared, leaving no fat. But when liver and muscle of beef were treated in the same way, the fat remained, while the fibre was removed. These experiments, so far as they go, favour the hypothesis which he has adopted, but they are not so numerous as to confirm his opinion.

Mineral Waters.

DCCCCLXXXVII. The term *mineral* is applied only to those waters which, in consequence of the presence of foreign substances in solution, act medicinally upon the system.

They have been divided into four kinds, according to the nature of the foreign matter which predominates in them. These are, 1. The Acidulous, 2. The Sulphureous, 3. The Saline, 4. The Chalybeate.

DCCCCLXXXVIII. 1. *Acidulous waters.* There are very few of this class which do not owe their properties to the presence of carbonic acid. In some cases however the acid has proved to be the sulphurous, or sulphuric, or boric. Carbonated waters have an acidulous taste, sparkle when poured into a glass, produce numerous air-bubbles when gently heated or even on exposure to the atmosphere, and frequently burst the bottles in which they are contained. They give a red colour to infusion of litmus when the gas amounts to $\frac{1}{16}$ of the volume of the water. If the water have been previously boiled, it produces no change on vegetable colours; and if water, which has not been heated and which has changed litmus to a red, be exposed for a time to the air, the original colour will be restored. Lime-water renders these waters turbid, and a white precipitate subsides, which is soluble with effervescence in acetic acid. The transparency of the mixed liquids may likewise be immediately restored by the addition of a few drops of an acid which is capable of forming a soluble salt with lime. If the mineral water be added in excess to lime-water, the precipitate as it forms will be redissolved as the lime apparently unites with two proportions of carbonic acid, the bi-carbonate being soluble. Lime-water will discover the presence of a grain of carbonic acid dissolved in 14,000 grains of water. If magnesia be present in combination, it will be precipitated by the lime-water; but where this is suspected, the water may be first tried by adding lime-water, redissolving the precipitate in a sufficient

quantity of muriatic acid, and then dropping into the liquid solution of pure ammonia by which the magnesia, if there be any, will be separated.

Carbonated waters likewise frequently contain carbonates of lime and soda, and carbonate of iron.

DCCCCLXXXIX. 2. *Sulphureous waters.* These waters give out the odour of sulphuretted hydrogen, and have a nauseous taste. They exist in many parts of the United States, particularly in the interior of New York and Virginia. They are there called Sulphur springs, and as the gas is gradually decomposed on exposure to the air, their margins are covered with sulphur.

These waters redden the infusion of litmus, precipitate nitrate or acetate of lead of a dark brown colour, tarnish the bright surfaces of silver, and on exposure to the air become turbid and deposite sulphur. The same effect is produced by nitrous acid; it communicates oxygen to the hydrogen and the sulphur separates.

Both carbonic acid and nitrogen are sometimes found in these waters. And from the analyses of the Ballstown waters by Drs. Seaman and Meade, it appears that azote also exists in carbonated waters.

DCCCCXC. 3. *Saline waters.* These owe their peculiar properties to the presence of earthy and alkaline salts, in different numbers and proportions in different waters. The most common are sulphates, muriates, and carbonates of soda, lime, and magnesia, and carbonate and sulphate of iron. Carbonic acid and azote likewise exist in many of them. The waters of Ballstown and Saratoga, besides salts, contain more than their own bulk of carbonic acid.

DCCCCXCI. In order to ascertain in a general way the nature of salts thus dissolved, it will be proper to evaporate the water as far as can be done without separating any foreign matter; because the salts, when dissolved in a great excess of water, are not always to be detected even by the most delicate reagents. If it be wished to determine what

acids are in combination, the following are the appropriate tests—of *sulphuric acid*, any of the soluble salts of barytes in solution when dropped into the liquid will produce a turbidness and subsequent precipitation of a white powder; the same effect will follow the addition of solution of nitrate or acetate of lead. In order to determine whether these precipitates be sulphates or carbonates, a sufficient quantity of nitric acid may be added which will dissolve the solid if it be a carbonate, but will have no effect if it be a sulphate. The salts of barytes are less ambiguous and much more delicate tests of sulphuric acid, than those of lead. The muriate of barytes is generally preferred—of *muriatic acid*, the soluble salts of silver, such as the sulphate, nitrate, and acetate, produce with this acid a white precipitate, which soon acquires a faint tinge of blue. But if sulphuric acid be present, a sulphate, provided either of the two last salts be employed, will be separated. Hence if a sulphate exist in solution it should be previously decomposed by a salt of barytes, or the sulphate of silver should be used. It is affirmed by Pfaff, that nitrate of mercury, formed without the aid of heat, is a more delicate test of muriatic acid than the salts of silver, the former producing a precipitate with one part of the acid, diluted with 300,000 parts of water, while the latter will have no effect on the same quantity of muriatic acid in more than 70,000 parts of water—of *boracic acid*, which is very rarely met with in mineral waters, the best test is acetate of lead, producing a precipitate which is soluble in nitric acid of the specific gravity of 1.30. But in order to be certain that the precipitate is borate of lead, it will be necessary previously to saturate any uncombined alkali or earth with acetic acid, and to remove sulphuric and muriatic acids, if either or both be present, by their appropriate tests—of *carbonic acid*, the tests have been already mentioned. *Nitric acid* forms no insoluble compound with any of the salifiable bases, and is not therefore to be detected by any direct test. *Sulphurous acid* may be detected by its odour, by its action on vegetable

blues, producing a permanent red, by destroying the colour of infusion of red roses previously reddened by an acid, and by the addition of nitrous acid to the water in a close vessel which after a time changes it to sulphuric acid, and then precipitating by muriate of barytes.

The salifiable bases united with these acids may be discovered in the following ways.

DCCCCXCII. Carbonated alkalies may be discovered by their effects upon vegetable colours producing a green in infusion of red cabbage, a violet in that of litmus, and a brown in tincture of turmeric; or by restoring the original colours in these liquids when previously changed by the action of acids. The earthy carbonates in large proportion produce the same effects. The earthy and metallic carbonates are precipitated when the water is boiled, as they are held in solution by carbonic acid.

The pure fixed alkalies precipitate all the earths and metals, but they are not delicate tests, because the solutions must be concentrated to produce this effect. Thus 1 part of sulphate of alumina in 125 parts of water escapes precipitation. Nor is much to be learned when different substances are thus thrown down in mixture. The alkaline carbonates are more useful, as they are much more delicate, and indicate the presence of an earthy salt or salts, the nature of which may be determined by subsequent examination. Bi-carbonate of potash, or carbonate of soda may be employed.

Alumina may be discovered by its being precipitated by carbonate of ammonia, and the precipitate being soluble in a boiling hot solution of potash, but insoluble in distilled vinegar. It is likewise separated by succinate of ammonia.

The appropriate test of *Lime* is oxalic acid, either alone, or in combination with ammonia. It separates this substance from all the other acids. When any one of the mineral acids is present, or is disengaged from its combination, the oxalic acid may be decomposed, or the oxalate of lime may be dissolved; but by previously combining the oxalic acid with a

basis, ammonia, for example, that basis will unite with the acid separated and prevent the consequences just stated. If the lime have been super-saturated with nitric or muriatic acid, it will be necessary to neutralize the excess with pure ammonia, before this test can be applied with success.

The identifying of *magnesia* in mineral waters is more difficult, because there is no direct test of its presence which does not act either upon lime or carbonic or sulphuric acid. Magnesia is precipitated by lime-water and by ammonia; but subsequent examination is necessary to decide whether the precipitate be magnesia, or carbonate or sulphate of lime. This is upon the presumption of the existence of carbonic acid or sulphuric acid; hence before these tests are employed, these substances, if present, should be removed. Carbonate of ammonia does not precipitate magnesia from its combinations; but if carbonate of ammonia be first added to the water, if the liquid be filtered, heated to nearly its boiling point, and then saturated with pure ammonia, the precipitate, if there be any, may be presumed to be magnesia. The best method of detecting this earth is that proposed by Dr. Wollaston.

It depends upon the property of bi-carbonate of ammonia to dissolve carbonate of magnesia, and to form with phosphoric acid a triple compound of ammonia, magnesia, and the acid which is insoluble. The ammoniacal solution should be formed of carbonate of ammonia which has been exposed spread on paper for some hours to the air. This solution is to be added to the water which has been previously concentrated; no precipitation will take place, but if solution of *phosphate* of soda be then added, the magnesian salt will be formed and separated.

The other earths found in mineral waters, though rarely, are silex and pure lime. The former exists in the waters of the celebrated Geyser fountains in Iceland. These waters are hot. Lime in its caustic state has likewise been discovered in a hot mineral water near Pisa in Tuscany.

DCCCCXCIII. By the means just pointed out, the nature of the salts, &c. existing in simultaneous solution in water may be ascertained. This having been effected, the knowledge thus acquired may be considered as a preliminary step towards an accurate analysis of the solid contents to discover the relative proportions of the different saline compounds. This is a work of considerable difficulty when several salts are mixed, and it requires a thorough practical knowledge of affinities and of the use of reagents, and of the composition of saline compounds. The separation is effected by the use of alcohol, and of water, by repeated solutions and crystallizations, and guarding against all the circumstances which occasion loss, or those which introduce inaccuracies into the results from impurity of the agents. The general methods of analyzing mineral waters may be found in the works quoted in the margin.*

DCCCCXCIV. Until lately it had been supposed that the products obtained in the analysis of a mineral water existed as such in solution, and that the nature of these products actually indicated the composition before separation. But Dr. Murray has shown that this is not necessarily the case; he has rendered the opinion, that during the analyses, the proximate elements of the compounds combine in many cases in a different manner, extremely probable; and hence that the salts obtained did not previously exist in the liquid. This very ingenious idea has been illustrated by him in the 6th volume of the *Annals of Philosophy*, and more at large in the 7th volume of the *Edinburgh Philosophical Transactions*. It is likewise stated in the third volume of his *Chemistry*. Thus for example, an English pint of the mineral water of

* Murray's *System of Chemistry*, iii. p. 675. 4th edit. Thomson's *System*, iii. p. 223. 5th edit.

Thenard. *Traité de Chimie*, t. iv. p. 154. 2d edit. Much useful information may likewise be obtained from Henry's *Chemistry*, 7th edit. and the papers of Dr. Murray, in the 6th vol. of *Annals of Philosophy*. and the 7th vol. of *Edinburgh Transactions*.

Dunblane afforded 18 grains of muriate of lime, 24 grains of muriate of soda, and 3.5 grains of sulphate of lime. These, according to the common opinion, would have been considered as its ingredients. But it is possible to give a different view of its composition. The sulphuric acid may exist in it in the state of sulphate of soda; and when the solution is concentrated by evaporation, this salt re-acting upon the muriate of lime, will form corresponding portions of muriate of soda and sulphate of lime. On this view a pint of the water will contain, estimating the equivalent quantities from the products of evaporation, 20.8 of muriate of lime, 21 of muriate of soda, and 3.7 of sulphate of soda.

There is no possibility of proving from the production of sulphate of lime with muriate of soda by evaporation, that either had existed as an original ingredient.

Dr. Murray states that the contents of a mineral water may be considered under three points of view. 1. Where the ingredients are in simultaneous combination. 2. Where they are combined according to the products of evaporation. 3. Where during the analysis they are combined upon the principle, that compounds of greatest solubility are formed which remain in solution while others of sparing solubility are precipitated, the results depending upon the mutual re-action of the elements of the saline compounds. With regard to the probability of these different opinions, this great chemist thinks it can scarcely be doubted, that the last is just. The theory then which he proposes is, that those products which are of sparing solubility are formed by decomposition, and that the binary compounds of greatest solubility are the original ingredients.

Among other illustrations of this doctrine, Dr. Murray adduces sea-water as an instance favourable to his views. A pint of this liquid afforded 14.4 grains of sulphuric acid, 97.7 of muriatic acid, 96.3 of soda, 14.8 of magnesia, and 2.9 of lime = 226.1 grains. These, combined according to the products of evaporation, will give 180.5 grains of muriate of

soda, 25 of muriate of magnesia, 15.5 of sulphate of magnesia, and 7.1 of sulphate of lime. But if combined according to the principle that the compounds of greatest solubility are those which exist in the liquid, the proportions will be of muriate of soda 159.3 grains, muriate of magnesia 35.5, muriate of lime 5.7, sulphate of soda 25.6. The last is considered as most correct, and as the mode of analysis, by which the most accurate proportions are obtained.

DCCCCXCV. 4. *Chalybeate waters.* The chalybeate waters have a styptic, metallic taste, more or less strong, and on exposure to the air for some time deposite a yellow coloured substance, or their surface becomes covered with a film of the same colour. The iron, to which they owe their properties, is in the state of protoxide, and in by far the greatest proportion, it is held in solution by carbonic acid. It happens sometimes, though rarely, that it is combined with sulphuric acid. On exposure to the air the iron becomes converted into peroxide and is precipitated. The most delicate tests of these waters are tannin, such as exists in galls, and triple prussiate of potash. With infusion or tincture of galls, iron in solution produces a bluish black colour. It often happens, however, that when this test is added to fresh mineral water which is known to contain iron, no change of colour will be immediately perceived, but that the usual change takes place after exposure to the atmosphere for a few hours, owing to the conversion of the protoxide into peroxide. The degree of colour is varied by the presence of other compounds; alkaline carbonates and earthy salts produce a violet; neutral alkaline salts, a dark purple; sulphuretted hydrogen, a purplish red; and sulphate of lime, a whitish precipitate, which changes to a black. According to Mr. Phillips, when iron is in the state of protoxide, the presence of carbonate of lime heightens the colour from galls, but if in that of peroxide, it diminishes it so much, that if in minute quantity it cannot be detected.

If galls produce no precipitate in a chalybeate water after it has been boiled and become clear, it is a proof that the iron is held in solution by carbonic acid.

Triple prussiate of potash or ferruretted chyazate of potash forms, with iron in solution, prussian blue, provided the metal be in the state of peroxide. But the composition of this salt is so complicated that no dependence can be placed upon its results. From the mode in which it is commonly prepared it contains an excess of potash, and if any free acid be present it is decomposed, the acid unites with a portion of the iron of the ferruretted chyazic acid, and forms a compound, upon which the prussiate of potash re-acts, and forms prussian blue, even if no iron have been present in the water. When it is employed, supposing other circumstances to be favourable, a deduction of 0.25 parts in the precipitate should be made.

Benzoate of ammonia has been recommended by Berzelius as a test of iron. Ammonia, in combination with the acid of amber, in the form of succinate of ammonia, has likewise been employed. "I have found," says Dr. Murray, "upon the whole, the best method is to add to the liquid evaporated, with the previous addition of a minute portion of muriatic acid, a minute quantity of ammonia, so as to produce the slightest possible alkaline excess; if the quantity of oxide be considerable, it is immediately thrown down; if it is in small proportion, it separates slowly from the liquid for a day or two. The precipitate is washed and converted into red oxide by a red heat."

Dr. Murray, from whose memoirs on this subject we have extracted the greatest part of the above, has given a *general formula* for the analysis of mineral waters, which may be found in the works already quoted.

APPENDIX.

SINCE the publication of the first volume, some important additions have been made to the science of Chemistry, which will require to be noticed. These are, 1. a new compound of oxygen and hydrogen, discovered by M. Thenard, and called by him oxygenated water. 2. A compound of hydrogen and carbonic oxide, discovered by Dr. Thomson. 3. A compound of sulphurous acid and sulphuretted hydrogen, by the same chemist. 4. Two new alkalies, beside the one described in the present volume by the name of Lithia. 5. A new acid of sulphur.

1. *Oxygenated Water.*

The method, in all its details, of preparing this liquid has been given by M. Thenard in the 11th volume of the *Annales de Chimie*; and the memoir has been translated and published in the 8th volume of the *Quarterly Journal of Science and the Arts*.

Nitrate of barytes obtained free from iron and manganese, which may be done by adding to its solution a small excess of barytic water, filtering, and crystallizing, is to be decomposed by exposure to heat in a perfectly white porcelain retort. Then, being divided into pieces as large as the end of the thumb, it is to be introduced into a luted glass tube sufficiently large to contain from 2lb 4oz. to 3lb 6oz. The tube is to be surrounded with fire, and when heated to dull redness, a current of dry oxygen is to be passed through it. However rapid the current may be, the gas will be com-

pletely absorbed until the barytes is saturated, when the gas will pass out at the other end. By this arrangement a deutoxide of barium of a light gray colour will be formed, which is to be put into stoppered vessels.

A certain quantity of water, for example $4\frac{1}{4}$ pints, is then taken, and as much fuming muriatic acid is added, as will saturate 232 grains of barytes. The vessel containing the liquid is placed in snow or ice which should be renewed as it melts. Then the deutoxide amounting to 185 grains, after having been slightly moistened and rubbed by portions in a mortar of agate or glass, to the consistence of a paste, is to be placed in the liquid by means of a box-wood spatula, solution without effervescence takes place, and then sulphuric acid pure and concentrated is to be added drop by drop, stirring the fluid, until there is a slight excess of acid, which is known by the precipitation of sulphate of barytes in flocculi. Deutoxide of barium is again added as before, and it is decomposed by the addition of more sulphuric acid. The liquid is then to be filtered and a small quantity of water is made to pass the filter, and added to the first liquid. These operations are then to be repeated, the filtration being performed after every two solutions and precipitations. By using the quantity of muriatic acid mentioned, from 29 to 32oz. of deutoxide may be operated upon, and a fluid will be obtained charged with 25 or 30 times its volume of oxygen. If it be required to be further oxygenized, more muriatic acid must be added. Thenard has many times succeeded in charging the fluid with 125 times its volume of oxygen, by adding muriatic acid enough to dissolve 463 grains of the deutoxide; but he has ascertained that when the fluid contains nearly 50 volumes, it allows so much gas to escape from day to day that there is no advantage gained in continuing the oxygenization above that point.

When the fluid is oxygenated up to the required point, it is to be saturated with the deutoxide while in the ice, silex and alumina, with a little of the oxides of iron and manga-

nese, subside ; the whole should then be thrown quickly upon a cloth, enclosed and strongly compressed. Two persons will be required here, as the operation must be done rapidly, otherwise the manganese will produce a considerable disengagement of oxygen. To the liquid is added barytic water drop by drop, until it is in slight excess, if any precipitate take place, the fluid is to be filtered quickly by means of several separate papers, and at the conclusion the filters should be compressed in a cloth.

The fluid consisting only of muriatic acid, water, and oxygen, is to be replaced in the first vessel, neutral solution of sulphate of silver is added, chloride of silver precipitates, and sulphuric acid takes the place of the muriatic in the liquid. When the quantity of sulphate of silver added is sufficient to decompose all the muriatic acid, the fluid suddenly becomes clear. It is of consequence that there remain in the liquid neither sulphate of silver nor muriatic acid. The fluid is to be passed through a filter. It now contains water, oxygen, and sulphuric acid. To remove the last it is rubbed in a mortar, surrounded with ice, with pure slaked barytes, added in small portions at a time, and when it is combined with the acid, so that the liquid scarcely acts upon litmus paper, the fluid is filtered, and the little acid remaining is saturated with barytic water, and the filtering with the above precautions repeated. The excess of barytes may then be removed by a few drops of sulphuric acid. It then constitutes pure oxygenated water mixed with common water. They may be separated by putting the liquid into a glass with a foot, setting this glass in a broad capsule of glass two thirds full of strong sulphuric acid, depositing the apparatus in the receiver of an air-pump, and exhausting the air. Pure water evaporates more rapidly than that which has been oxygenated, and hence at the end of 2 days the liquid will contain perhaps 250 times its volume of oxygen. When it becomes very concentrated bubbles of gas rise to the surface. The fluid is in its most concentrated state when at the tem-

perature of 57.2° Fah. and at mean atmospheric pressure it gives 475 its volume of oxygen. The properties of oxygenated water are the following.

It is a transparent and colourless liquid, destitute of odour in common circumstances, but when vaporised in the exhausted receiver of a air-pump, has a peculiar smell. Its taste is astringent and its specific gravity when saturated is 1.45. When applied to the skin it renders it white, and if the application be continued, acts upon it like a synapism. When dropped into water it falls through it like sulphuric acid in the same liquid. It is however capable of mixing with water in all proportions. It decomposes and is decomposed by several of the metals and metallic oxides. When dropped upon oxide of silver, explosion immediately takes place, the metal is reduced and the water disoxygenized, a great degree of heat and some light accompany this action. It is likewise decomposed when added to the metals themselves. The same effect is produced by many animal substances. When fibrin, a portion of lung or of kidney is introduced into a tube standing over mercury and containing oxygenated water, the latter is rapidly decomposed and gives off many times its volume of oxygen. But if much oxygenated it is not decomposed by urea, albumen, either solid or liquid, or gelatine.

Water when saturated holds condensed 616 times its volume of oxygen.

2. *Hydroguretted Carbonic Oxide.*

This name has been given by Dr. Thomson to a compound discovered by him during his researches into the composition of the Triple Prussiate of potash in the year 1818.*

It is obtained by the action of sulphuric acid on the salt above mentioned, when aided by heat. The process is as follows. Two hundred grains of prussiate of potash are to be put into a tubulated retort, connected with a common wa-

* Annals of Philosophy, vol. xii. p. 102.

ter trough; to these are to be added four drachm measures of sulphuric acid, specific gravity 1.844, and the mixture is to be heated by a lamp, effervescence takes place, and an elastic fluid in abundance will be disengaged. It may be caught over water. The gas has the following properties. It is colourless and transparent, possessing an odour which though neither strong nor disagreeable, is peculiar, and a taste which is rather aromatic, and leaves a hot impression in the mouth. Its specific gravity by experiment is 0.993, by calculation 0.995. It suffers no change on exposure to light over water.

When fired, it burns readily with a flame of a deep blue colour; if previously mingled with oxygen gas, it detonates by the electric spark.

From the results of several experiments, Dr. Thomson concludes that 3 volumes of the gas require for complete combustion 2 volumes of oxygen, and the results are water and carbonic acid. Hence he infers that the gas itself consists of 3 volumes of carbonic oxide, and 1 volume of hydrogen, condensed into 3 volumes. Hence it appears that one volume and a half of the oxygen is employed in this combustion in converting the carbonic oxide into carbonic acid, while the other half volume of oxygen combines with the volume of hydrogen and forms water.

From its composition he has called it *Hydroguretted Carbonic oxide*.

From the production of this gas, Dr. Thomson thinks that a strong argument may be drawn in favour of the opinion of Mr. Porrett, that the acid in triple prussiate of potash contains hydrogen as one of its elements; and that according to the conclusions of that ingenious chemist this acid, instead of being a ferro-cyanic acid, is in fact a ferruretted chyazic acid.

5. New Compound of Sulphurous acid and Sulphuretted Hydrogen gases.

In volume first under the head of Sulphuretted hydrogen it is stated that when that gas is mingled in certain proportions with sulphurous acid gas, the oxygen of the latter combines with the hydrogen of the former, and the sulphur of both is precipitated. This subject since then has been examined by Dr. Thomson, and it has been proved by him that the gases, instead of decomposing each other, enter into combination, and produce a peculiar solid and acid compound. The proportions required for complete condensation are three volumes of sulphuretted hydrogen to two of sulphurous acid.

The product is a solid of an orange yellow colour, of a taste, at first sensibly acid, then hot and peppery, the impression lasting for some time. When dry it produces no effect upon litmus paper, but if the paper be ever so slightly moistened, its colour changes to a red. Hence it possesses acid properties. It cannot be applied to any useful purpose in chemistry, as it was decomposed by all the liquid bodies with which it was brought into contact by Dr. Thomson, and as it does not unite with the salifiable bases when presented in a dry state. The acid which changes vegetable colours can be neither the sulphurous nor sulphuric, for when agitated in barytic water, no immediate precipitation takes place, though if the mixture be boiled, a dirty gray precipitate at last falls. It requires a higher heat than sulphur for its fusion, but like that substance it first becomes soft and ductile. If the heat be continued, a kind of effervescence takes place and the compound is converted into common sulphur.

When agitated with water, the latter acquires an acidulous taste, becomes milky, and speedily deposits a portion of sulphur. The same effect is produced in alcohol. It does not act on potash unless water be present, and then it forms common sulphuret of potash.

The other properties of this compound are of little consequence.

It is considered by Dr. Thomson as a ternary compound of sulphur, oxygen, and hydrogen, but as it possesses the properties of an acid only in a very weak degree, Dr. Thomson thinks it a sufficient proof that Dr. Murray's notion, that the greatest degree of acidity is given to bodies by the joint union of oxygen and hydrogen, is not countenanced by chemical facts, nor consistent with the phenomena of the science.*

This opinion is controverted by Dr. Murray, and this distinguished Chemist has satisfactorily shown, that the discovery of the new compound, instead of weakening, gives confirmation to the theory of the constitution of acids which he has supported. His reasoning is that in a compound of sulphur in which there is a relation of sulphur to oxygen, and in addition to this of hydrogen to the sulphur, the radical receives the acidifying influence of both and exhibits high acid powers, as e. g. in sulphuric acid; but where one portion of the sulphur is in that relation to oxygen which constitutes sulphurous acid, and *another portion of sulphur* is in that relation to the hydrogen which constitutes sulphuretted hydrogen, then no augmentation of acidity is to be expected; but, on the contrary, from the reciprocal action of oxygen and hydrogen, it must be rather below the mean acid power which is displayed in the two binary compounds.†

This is the case with the compound in question.

4. *Strychnine.*

This substance was discovered by M. M. Pelletier and Caventou. It is obtained from *St. Ignatius's bean* by the following process. The seeds reduced to powder by a rasp are to be digested in ether, by which a thick oily substance of a faint green colour is obtained, transparent while fluid. The

* Annals of Philosophy, vol. xii. p. 441.

† Ibid. Ibid. xiii. p. 125.

ether being withdrawn, the mass is to be treated with alcohol until all that is soluble is dissolved; the solution after filtration when cold, is then evaporated; and the residue is a brownish yellow bitter substance, soluble in water and alcohol. A strong solution of this matter is to be treated with potash in solution, a precipitate falls, which, when washed with cold water, is white, crystalline, and very bitter. If not perfectly pure, it may be rendered so by solution in acetic or muriatic acid, and precipitating anew by potash, or magnesia; if the latter, the strychnine may be taken up from it by alcohol. This substance may likewise be obtained from the *nux vomica*.

Strychnine is white and may be procured crystallized in minute quadrangular prisms, terminated by low quadrangular pyramids. It is destitute of odour, but has a taste so powerful that it is easily recognised in a solution which contains but $\frac{1}{80000}$ part. It is neither fusible nor volatile, but is decomposed at the temperature of boiling oil, and the products are oxygen, hydrogen, and carbon. It operates upon vegetable blues like an alkali; it is soluble in water, requiring of that liquid at 50°. 2500 parts, and at 212°, 600 parts. It is much more soluble in alcohol. It operates violently upon the animal body.

Strychnine combines with the acids, and forms peculiar salts.

Sulphate of strychnine crystallizes in cubes, or if there be an excess of acid, in fine needles, soluble in 10 parts of cold water, having a very bitter taste, and decomposable by all the soluble salifiable bases, the strychnine being precipitated. It is permanent in the air. Nitric acid gives it a blood red colour. It is decomposed by heat. This sulphate consists of 90.5 of strychnine, and 9.5 of sulphuric acid.

Muriate—neutral—more soluble than the sulphate—crystals, fine prismatic, quadrangular needles in mamillated groups. Exposed to heat, muriatic acid is disengaged, and the strychnine decomposed.

Phosphate—is a perfectly soluble, crystallizable salt, the crystals being quadrangular prisms.

Nitrate—crystallizes in pearly needles, grouped in fasciculi. Some care is necessary in its formation. It unites with an excess of acid, crystallizing in needles. This salt has a very bitter taste, and acts more powerfully on the system than the base itself. It is soluble. When heated it is decomposed with a hissing noise.

The action of strong nitric acid on strychnine is interesting. It occasions changes of colour in the inverse order of the coloured rings of the third order. The same effect is produced by adding nitric acid to salts of strychnine, but then the red colour is more permanent. Sulphuric and muriatic acid have the like effect on the nitrate, by liberating the nitric acid. This change of colour produced by nitric acid on strychnine is considered as a valuable test of the presence of nitrates in mixtures of salts &c.; for this purpose a little strychnine or salt of strychnine is to be added to the suspected mixture with a little sulphuric acid; if a nitrate be present, the red colour will be produced.

By the action of nitric acid on strychnine, removing the excess of acid by an alkali, the strychnine is obtained of an orange or a yellow colour with its alkaline powers much diminished, but still capable of forming salts with the acid, which are red or yellow, according as it has been brought to the first or second state. The French chemists venture the idea that these may be protoxides and duetoxides of strychnine.

Carbonate, formed by double decomposition, exists as a flocculent magma, very little soluble in water, but readily so in solution of carbonic acid. The super-carbonate on exposure to the air loses its excess of acid, and the neutral carbonate precipitates in granular crystals. The vegetable acids likewise combine with strychnine.

It does not enter into union with carbon or sulphur, but with chlorine and iodine it acts like the other alkalies. If iodine and strychnine be boiled in water, they disappear in

part, and the solution, when filtered and evaporated, yields a white needle-form salt, which in fact is hydriodate of strychnine, with probably a quantity of iodate. When a current of chlorine is passed through strychnine diffused in water, the latter disappears, and the solution on evaporation yields crystals of muriate of strychnine.

Salts of strychnine are decomposed by the other alkalies and alkaline earths, but it decomposes metallic solutions; in some cases it forms with the latter triple salts, e. g. with sulphate of copper.

M. M. Pelletier and Caventou think they have discovered a new acid in these seeds, existing in combination with strychnine. They have called it *igasuric acid*.

Stychnine is the only active substance in *nux vomica*, *St. Ignatius's bean*, and *bois de couleurre* (*lignum colubrinum*, or snake-wood?) The salts are more active than the base, and there is no substance capable of forming with it innocuous compounds.*

5. *Delphine, a new vegetable Alkali.*†

M. M. Lassaigne and Feneulle, in a letter to M. Gay-Lussac, state that while analyzing the seed of the *Delphinium Stuphisagria*, they obtained a white, crystalline substance of a very acrimonious taste, becoming afterwards bitter, and discovering alkaline properties. It restores the colour of litmus changed red by acids, and acts with acids themselves like strychnine, morphia, and picrotoxine, with which it ought to be classed.

It is a fine white powder of a shining appearance, inodorous, sparingly soluble in water, but easily so in alcohol and ether. Thrown on burning coals, it melts, burns with a thick white smoke, of a peculiar odour, and leaves no residue.

* Quarterly Journal of Science, &c. vol. vii. p. 375.

† Journal of Science and the arts, viii. 155.

It forms very soluble salts with several of the acids.

It exists in the cotyledons of the stavesacre in combination with malic acid, and is the cause of their acrid taste.

It may be obtained from them by the same method as was practised by M. Robiquet to separate morphia from opium (see p. 523 of this volume.)

These chemists have given this substance the name of *Delphine*.

6. *New Acid of Sulphur.*

M. M. Welter and Gay-Lussac have discovered a new acid of sulphur and described its properties and combinations. In composition it is intermediate between sulphurous and sulphuric acids. They have named it *hyposulphuric acid*, and its saline compounds are called *hyposulphates*.

It is prepared by passing a stream of sulphurous acid gas into water, holding peroxide of manganese in suspension; a neutral solution is obtained of sulphate and hyposulphate of manganese. They are decomposed by the addition of barytes in excess; sulphate of barytes precipitates, hyposulphate remains in solution. The excess of barytes in the liquid is removed by carbonic acid, and the whole being heated, the hyposulphate is obtained.

It is advantageous to crystallize the salt to free it from a small portion of lime. If sulphuric acid, in sufficient quantity just to neutralize the barytes, be added to this salt, hyposulphuric acid will be obtained.

It is inodorous, of an acid taste, and in its strongest state of the specific gravity of 1.347. It does not appear capable of existing in the gaseous state. At the density of 1.347 it begins to decompose, gives out sulphurous acid and retains sulphuric acid. When very dilute it gives out, if heated, aqueous vapour, but soon begins to disengage sulphurous acid, and produce sulphuric acid. The heat of a water bath is sufficient to occasion this decomposition.

It is not altered at low temperatures by chlorine, strong nitric acid, nor red sulphate of manganese. It perfectly saturates

bases, and forms soluble salts with barytes, strontian, lime, oxide of lead, and probably with all the bases.

It dissolves zinc without being decomposed, and evolves hydrogen. It contains 2 proportions of sulphur, 5 proportions of oxygen, and a certain quantity of water, which appears essential to its existence in an uncombined form. These results were obtained by the decomposition of hyposulphate of barytes.

The following are the proportions of elements assigned to the acids of sulphur by these chemists.

	Prop.		Prop.	
Hyposulphurous acid	- 2	sulphur	2	oxygen.
Hyposulphuric acid	- 2	do.	5	do.
Sulphurous acid	- - 1	do.	2	do.
Sulphuric acid	- - 1	do.	3	do.

or if sulphur be considered as unity, then the ratio of oxygen in these acids will be—1, 2, 2.5, 3.

Hence they think that these acids should form two groups, the two first constituting one and the two last another. The distinction is thought necessary, because the quantity of sulphur in each of these groups is different, and because their composition cannot be expressed by terms of the same series; the salts also of each group have stronger analogies among themselves than they have with those of the other group.

The solutions of the hyposulphates alter but very slowly in the air; in general these salts are permanent at low temperatures, but are easily decomposed by heat, and by concentrated sulphuric acid.

Hyposulphate of barytes crystallizes in shining quadrangular prisms, exhibiting numerous facets. It suffers no change in the air, it is soluble in water, 100 of that liquid at 46.6° Fah. dissolving 13.94 parts; the solution is not altered by chlorine. By heating, it decrepitation takes place, water and sulphurous acid are disengaged, and neutral sulphate of barytes remains. It consists of 1 proportion of barytes 97, 1 of hyposulphuric acid 90, and 2 proportions of water 22.64.

Hyposulphate of potash crystallizes in cylinders, terminated in a plane perpendicular to their length.

Hyposulphate of lime—regular hexagonal plates, grouped in distinct masses.

Hyposulphate of strontian—crystals very small, apparently hexaedral plates.

Hyposulphate of manganese—very soluble—deliquescent.

The hyposulphuric acid is distinguished from the other acids of sulphur by the following properties. 1. By being converted into sulphurous and sulphuric acids, when heated. 2. By forming soluble salts with barytes, strontian, lime, lead, and silver. The characters of the *hyposulphates* are, 1. Solubility. 2. The absence of sulphurous acid when their solutions are mixed with acids, except the mixture heat of itself, or be purposely heated. 3. The liberation of much sulphurous acid at a high temperature, and their conversion into neutral sulphates.*

7. Compound Blow-pipe.

In the account of this instrument given in the first volume of this work, the author was inadvertently led into error respecting Mr. Cloud's claims to the invention of the compound blow-pipe. This term was first applied by Professor Silliman, and it should be considered as a general expression to be applied to all the varieties of the oxy-hydrogen blow-pipe. The author has been informed by Dr. Hare, that Mr. Cloud made "some change in the mode of propelling the gases, availing himself of an apparatus imitated principally from one in his (Dr. H's) laboratory, and in part from the common gas-holder." Dr. Hare had previously formed a compound gas-holder, which differs from Mr. Cloud's in being made of wood and copper, instead of metal only, and in having a flat reservoir (instead of a conical one) into which the water rose when displaced by the gas, instead of escaping below.

* Annales de Chimie, t. x. 312, or Journal of Science and the Arts, vii. 371.

EXPLANATION OF THE PLATE.

Fig. 1. Dr. Hope's Eudiometer. This instrument consists of two parts, one for containing the eudiometric liquid, and the other the air to be analyzed. The body (*a*) from 2 to 3 inches in diameter, has two orifices, that at *b* being horizontal and the other at *c* vertical; the former is provided with a glass stopper, while the latter is intended to receive the mouth of the tube *d*, which is ground for that purpose, and is graduated on the outside to tenths of cubic inches. The reservoir is filled with fresh-prepared hydro-sulphuret of lime or potash, and the tube, previously filled with the air to be examined, is inserted into it at *c*. The vessel is then agitated for a few minutes in such a way as to bring the liquid and the air into contact, the body *a* is then immersed under the surface of water, and the stopper at *b* is withdrawn. If any oxygen have been condensed, a vacuum will have been formed, and the pressure of the air will force the water proportionally into the vessel; the stopper is then to be replaced, and these processes are to be repeated until the liquid remains stationary. Then the quantity of oxygen which was present may be inferred by the height to which the fluid has risen in the tube.

Solution of green sulphate or muriate of iron, saturated with nitrous gas, may likewise be used as the eudiometric liquid.

Fig. 2 & 3. These figures represent the apparatus employed by M. M. Gay-Lussac and Thenard in the experiment of decomposing potash by iron. Fig. 2. is a gun-barrel, bent somewhat in the form of the letter S. Before the curvatures are given to it, the internal surface must be cleaned by stopping one end, introducing into the other diluted muriatic or sulphuric acid, and shaking the barrel so that every part shall be exposed to its action; after the liquid is poured out, the barrel is to be well washed with water, dried by linen or bibulous paper, and stopped at both ends.

The part which is to be exposed to heat from *a* to *b* is then to be covered with a lute, which should be formed of fine clay and sifted sand, in the proportion of 1 to 5, thoroughly incorporated,

and rendered so little plastic by the quantity of sand as to be applied with some difficulty. The lute should contain as little water as possible. The thickness of the lute over the iron should be about $\frac{6.3}{100}$ of an inch (16 millimetres.) It should, after the application, be allowed to dry for a few days in the shade and then in the rays of the sun or in a gentle heat, the rents, if there be any, being filled with fresh lute. The space from *c* to *d* is to be filled with clean iron turnings, and the barrel is then to be laid across a reverberatory furnace *fig. 3*, having its internal diameter equal to about $11\frac{1}{2}$ inches, (30 centimetres,) the barrel at *a* supporting itself on the furnace, and at *b* being supported on a piece of brick. The two openings through which the barrel passes are to be carefully closed with lute, which on the inside should consist of that which is the most infusible. The cork is then to be withdrawn from *e*, and from $5\frac{1}{2}$ to $4\frac{1}{2}$ ounces of fused potash in fragments are to be introduced into the barrel and pushed down to *c* *fig. 2*. Thus the space from *f* to *c* will be filled with potash, while that from *f* to *e* will be empty. As a great deal of gas is extricated in this operation, and the other end of the tube is liable to be obstructed, a passage is given to the gas by fitting a curved glass tube into *e*, and causing its mouth to open into a vessel *g*, nearly filled with mercury and supported on a stand. Fire is then lighted in the furnace, and when the flame appears at the dome, pieces of linen moistened with water are to be applied to the part containing the potash to prevent it from melting, and a recipient is to be adapted to the gun-barrel at *h*, *fig. 2*. This consists of two pieces or tubes *i, k*, of copper, the mouth of the barrel being inserted into *i*, and the other extremity of *i* embracing *k*, from which passes a curved tube that may be made to open under the surface of mercury, as seen in *fig. 3*. The joinings of the tubes are to be closed with lute. Then by means of a double bellows the heat in the furnace is to be raised as high as possible; when this is effected, a semi-cylindrical pan is to be suspended below the barrel, reaching from *e* to *a*. The portion of the barrel from *a* to *c*, *fig. 2*, is to be heated by live coals, the potash contained in it will be melted and flow into that part which is intensely heated. A great quantity of hydrogen gas will be disengaged, and a portion of potassium will be formed and will be condensed at the extremity *h*.

and in the recipient *i, k*. When the production of gas nearly ceases, another portion of the potash higher up in the barrel is to be heated, the gas will again come over, and these processes are to be repeated until no more hydrogen is disengaged.

It is very essential that too much potash should not be melted at one time, because in that case the temperature in the first part of the barrel would be reduced too low to effect the decomposition of the potash. Hence the reason why the alkali is used in fragments and not in a single piece. The best sign that the experiment goes on well is the rapid production of gas, without the disengagement of very thick vapours at the extremity of the glass tube *l*. The duration of the experiment from the time of the melting of the first portion of potash should be more than an hour.

When it is finished, the tube at *e* should be withdrawn, the mouth of the barrel and that of the tube at *l* being closed with lute. The barrel is withdrawn from the furnace, and cooled by the affusion of water, which likewise detaches the lute.

In order to obtain the potassium, which is condensed at *h*, and flows for the most part into the recipient *i, k*, the lute is removed at *h*, the mouth is closely stopped, a little oil of naphtha is poured into the recipient, the two pieces are separated, and the metal contained in them is made to fall into another portion of naphtha. The potassium thus obtained is commonly pure, and it may be best preserved by giving it a spherical form and keeping it in naphtha. By cutting off the barrel at *b*, and plunging the end in naphtha, the potassium in it may be obtained by introducing into it a cylinder of iron nearly of the same diameter and detaching it from the surface.

It happens that generally only about half the potash employed is consumed in the experiment.

The iron turnings combine with some of the potassium and form an alloy.

The nature of the lute, and its application, and drying, are circumstances which have an important influence upon the success of the experiment. If it do not contain enough sand, or if it be badly applied or dried, it either vitrifies and runs, or it falls off and exposes the iron to oxidizement and fusion.

As this process of M. M. Gay-Lussac and Thenard is troublesome and expensive, different methods have been proposed to simplify it. That of Dr. Hamel, stated in *vol. 5 of the Annals of Philosophy*, deserves to be consulted. He obtained usually two ounces of potassium at one experiment.

Mr. Howard proposes to introduce into a luted gun-barrel, the touch-hole of which is stopped and the breech screwed, a mixture of iron turnings and potash, the upper part being cut off and the ends fitted into each other by grinding. A tube of copper is introduced into the upper part of the barrel, the two parts being then united and a tube leading from it and opening under mercury being adapted, the portion containing the materials is then heated sufficiently high to decompose the potash, and the potassium after the operation will be found in the tube.

I had previously succeeded by a method similar to this, but more simple. The lower part of a gun-barrel properly closed and about 16 inches in length was luted, a mixture of dry potash and clean iron filings was introduced into it, a tube of copper was then placed in it but out of reach of the strongest heat, and a glass tube was connected with the mouth and opened under oil of turpentine. Heat was applied until the lute and part of the barrel began to melt. On cooling it I procured 30 or 40 grains of very good potassium which had condensed in the tube, and as much of an alloy of potassium and iron from the barrel itself. I have repeated this experiment 5 times; in 2 it was successful, in 3 unsuccessful.

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Pulvis fulminans	-	II. 60	Tellurium	-	187
Pyro-ligneous acid	-	348	Cerium	-	189
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malic acid	-	334	Bismuth	-	197
Pyrometers	-	I. 74	Copper	-	203
Pyrophorus	-	II. 31	Uranium	-	210
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	Q.		Nickel	-	234
Quick-lime	-	98	Gold	-	239
Quicksilver	-	212	Silver	-	248
	R.		Platinum	-	256
Radiant heat	-	I. 119	Rhodium	-	266
Radical vinegar	-	II. 392	Palladium	-	268
Radicle	-	364	Sap	-	369
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Realgar	-	II. 155	Sandarach	-	II. 315
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Rete mucosum	-	480	Shell, composition of	-	474
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Rhodium	-	264	Silicon	-	353
Rochelle salts	-	342	Silicated fluoric acid	-	356
Rock-crystal	-	I. 361	Silk	-	II. 477
Roots	-	II. 363	Silver	-	244
Rosacic acid	-	428	Sinews	-	479
Rosin	-	310	Size	-	405
Rum	-	381	Skins	-	480
	S.		Smalt	-	194
Sacchilactic acid	-	429	Soda	-	72
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Strontian	93	Platinum	255
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